WILL THE ATOM UNITE THE WORLD?

To the Senator
Clinton P. Anderson
with the compliments
of the author
A. Angelopoulos
Geneva, January 1958

BY THE SAME AUTHOR

Die Einkommensverteilung im Lichte der Einkommensteuerstatistik (*Probleme des Geld- und Finanzwesens, herausgegeben von Prof. Dr. Br.* Moll. *Band XII*). Leipzig, 1931.

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Angelos Angelopoulos

WILL THE ATOM UNITE THE WORLD?

ECONOMIC, SOCIAL AND POLITICAL ASPECTS OF THE ATOMIC AGE

Translated by C. R. Corner

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Chapter 1

THE NEW ASPECTS OF THE WORLD'S ENERGY PROBLEM

1. THE ENTRY OF THE ATOM INTO INDUSTRIAL LIFE

Humanity is in the fifteenth year of what is already being called 'the atomic age'. It was, in fact, on 2 December 1942 that the first atomic pile was put into action in a laboratory of the University of Chicago. This small-scale initial experiment proved the possibility of producing a self-sustaining chain reaction in uranium, and was the prelude to the intensive research that has led to such astounding progress in nuclear physics in the past few years. It was this first experiment that made possible the construction of the atom bomb and of the thermonuclear (or hydrogen) bomb, the production of radioisotopes and the generation of electric power by means of 'nuclear fission'.[1]

¶ *Can nuclear power become the principal source of energy by 1965?*

The harnessing of atomic energy—this age-long dream of scientists—is already a reality, an accomplished fact. From the moment when the first nuclear power station was brought into operation in the Soviet Union, when the American submarine *Nautilus* got under way on power generated by the world's first nuclear marine engine, and when it became possible to produce radioisotopes in large quantities, it was clear that the peaceful uses of the atom opened up immense potentialities for industry, agriculture, transport and public health and, indeed, for civilization in all its aspects. The International Conference on the Peaceful Uses of Atomic Energy, held at Geneva in

[1] Technical questions are dealt with in Chapter 4.

August 1955, heralded the entry of the atom into economic and social life and forecast the brilliant future that its wise utilization can bring to Humanity.

The reports presented at this conference, the discussions which took place there and the rich documentation that was made available on the subject of the results achieved by the countries which have taken the lead in nuclear research—particularly the information regarding nuclear power stations, the various types of reactors and the great variety of uses to which radioisotopes are being put—show that this new source of energy can, in numerous regions of the world, already compete with the conventional sources.

The progress achieved since the Geneva Conference has not only amply justified the optimism expressed at the conference, but has shown that the commercial exploitation of atomic energy as a power resource is not a future possibility but a present reality. On 27 June 1954 the world's first atomic power plant, with a capacity of 5,000 kilowatts, was put into operation in the Soviet Union. That country's Sixth Five-Year Plan contemplates the construction of atomic power stations which by 1960 will have a total capacity of from 2 to 2½ million kilowatts, or more than twice the combined output of all the electric power stations in Tsarist Russia.[1] Plans are being prepared for the successive construction of further atomic plants to provide the Soviet Union with electric power in ever growing quantity.

On 17 October 1956 Great Britain inaugurated her first atomic power station at Calder Hall. This plant has an initial capacity of 20,000 kilowatts, which is to be gradually stepped up to 90,000 kilowatts. On 19 January 1957 the British Press reported that work had begun on the site for a new nuclear power station at Bradwell in Essex. This plant, it is stated, will be 'the first truly economic nuclear generating station in the world to go into regular service'. A few days previously, work began on a power station at Berkeley in Gloucestershire. These two stations will be the first of the twelve contemplated in the government's White Paper of February 1955. Since that date the programme has been expanded to provide for a total

[1] *Etudes Soviétiques*, November 1956, p. 45.

of 19 nuclear power stations. These 19 stations will, it is hoped, be in operation by the end of 1965. They will have an installed capacity of between 5 and 6 million kilowatts and will cover at least a quarter of Britain's total electricity requirements.

In the United States, nuclear plants with a combined generating capacity of 700,000 to 1,000,000 kilowatts should have been completed and be in operation by 1960. Although the United States possesses an abundance of the conventional energy resources, it is calculated that if the continuance of maximum economic expansion is to be assured, the total power output of atomic plants should by 1975 be equivalent to 20–40 per cent of the country's present installed electric-generating capability, which amounts to close on 115 million kilowatts.[1]

A number of other countries (among which mention must be made of France, which on 12 October 1956 brought the G 1 nuclear reactor into operation at Marcoule, with a capacity of 5,750 kilowatts) are building or planning atomic power plants; and the Organization for European Economic Co-operation has proposed that its member countries should create one or more common enterprises for nuclear power development. According to the 'Three Wise Men' who were appointed to report on the potential production of nuclear power for Euratom, if the six countries of the European Coal and Steel Community are to achieve self-sufficiency it is essential that by 1975 atomic energy should be supplying about 20 per cent of their total power requirements.

Apart from the utilization of nuclear energy for the generation of electricity, several countries are carrying out research and experimentation with a view to the eventual use of this source of power for purposes of navigation, transport (lorries, motor-cars and aeroplanes) and space-heating. If, as we shall see later, the work at present proceeding on the development of controlled thermonuclear devices holds out the prospect that before long it will be possible to generate electric power on a commercial scale by controlled thermonuclear reaction, the

[1] See Report submitted on 30 January 1956 to the U.S. Congress Joint Committee on Atomic Energy by the 'Panel on the Impact of the Peaceful Uses of Atomic Energy' ('the McKinney report').

atom will rapidly become the world's principal source of energy. It is already certain that in the near future it will be possible to obtain from nuclear fission a constantly increasing quantity of electric power at a progressively decreasing cost.[1] It may indeed be asserted that before another 25 years have passed, that is to say by about 1980, atomic energy will be supplying at least one-half, and possibly three-quarters, of the power which the world will then be needing. This forecast does not appear unduly optimistic in the light of the present astoundingly rapid development of nuclear science and technology. Even the most optimistic of the scientists have said that their forecasts may well be outdated by the progress achieved. Speaking at Washington on 27 September 1956 in a panel discussion on 'Atomic Energy in Economic Development', organized by the International Bank for Reconstruction and Development, Sir John Cockcroft said:

'I am very conscious that in making this report most of what I have said will be overtaken by events during the next five years. It is certain, with the great power of creative technology today, that development will be rapid and capital costs of nuclear power projects will fall rapidly.'

It is because of the striking advance in nuclear technology that Great Britain has already felt able to make the above-mentioned expansion of the nuclear power production programme that was announced as recently as February 1955. The British White Paper of that month had expressed the opinion that power generated by nuclear fission would cover only a very small proportion of Britain's electricity requirements. It is now anticipated that as early as 1965 nuclear energy will be supplying a quarter of those requirements.

The harnessing of atomic energy for industrial use is thus already an accomplished fact, and there can no longer be any doubt that in the not distant future it will become the world's principal source of electric power.

¶ *World power resources and requirements*

Nuclear energy—a new and vast source of electric power—

[1] See the McKinney report, previously referred to.

makes its appearance at a crucial phase in human history. Specialists have for long been preoccupied by the question whether the earth contains sources of energy sufficient to satisfy mankind's future needs. A hundred years ago some scientists took a gloomy view of the outlook. They predicted that it would not be long before man would have no fuel with which to keep himself warm and cook his food. More recently, in the 1920s, other specialists foresaw the rapid exhaustion of liquid fuel resources. The prediction of the approaching exhaustion of the reserves of the conventional forms of energy was based in part on the statistical concept known as 'proved reserves'. It has been belied both by the locating of many new deposits and by the discovery of new sources of power. In the course of time there has been a succession of important changes in the pattern of the world's energy economy. Before 1880 wood was the principal fuel. From then onwards wood became progressively displaced by coal. In 1900 coal furnished 92 per cent of the world's energy output, but during the present century its importance has declined in proportion as that of oil, gas and water power has increased. It is a curious fact that water power is still only a secondary source of supply, taking the world's energy economy as a whole. It accounts, in fact, for only 1.8 per cent of total output. None the less, its contribution to the production of electricity is continually increasing and, indeed, about one-third of total production now comes from hydro-electric power stations.

The following table shows, in percentages, the changes since 1900 in the structure of world consumption of the various commercial sources of energy:[1]

Year	*Coal*	*Lignite*	*Petroleum*	*Natural gas*	*Water power*	*Total*
1900	92.0	2.9	3.5	1.2	0.4	100
1920	84.5	3.5	9.1	2.3	0.6	100
1940	69.0	5.0	19.3	5.5	1.2	100
1950	56.7	4.4	27.1	10.2	1.6	100
1955	49.5	4.6	31.8	12.1	2.0	100

[1] See document P/1116: 'Contribution of Nuclear Energy to Future World Power Needs', prepared by the United Nations and presented at the Geneva atomic conference. The figures for 1955 are estimates made by the author.

For the period 1948–1953 the average annual percentage rate of increase in the consumption of the various types of energy was as follows:[1]

Coal	1.0
Lignite	8.4
Petroleum	7.1
Natural gas	10.3
Water power	8.6
Total power	4.0
Electric power	3.6

It will be seen that the consumption of petroleum and natural gas is increasing to a considerably greater extent than that of coal.

Obviously it is here a question of power considered from the *commercial* angle, that is to say of the solid and liquid fuels, natural gas and water power only, and not of power derived from non-commercial sources (fuel wood, bagasse and other vegetal fuels). As countries become industrialized, the use of the non-commercial sources of power is progressively replaced by the use of the commercial sources. Whereas in 1860 the commercial sources accounted for only 27.4 per cent of the total utilization of power, in 1953 those sources covered 83.7 per cent of all requirements. Here is a table showing the distribution of the total production of power (commercial and non-commercial) for the year 1952, the calorific value being expressed in megawatt-hours (mwh):[2]

[1] United Nations, op. cit. P/1116, p. 20.

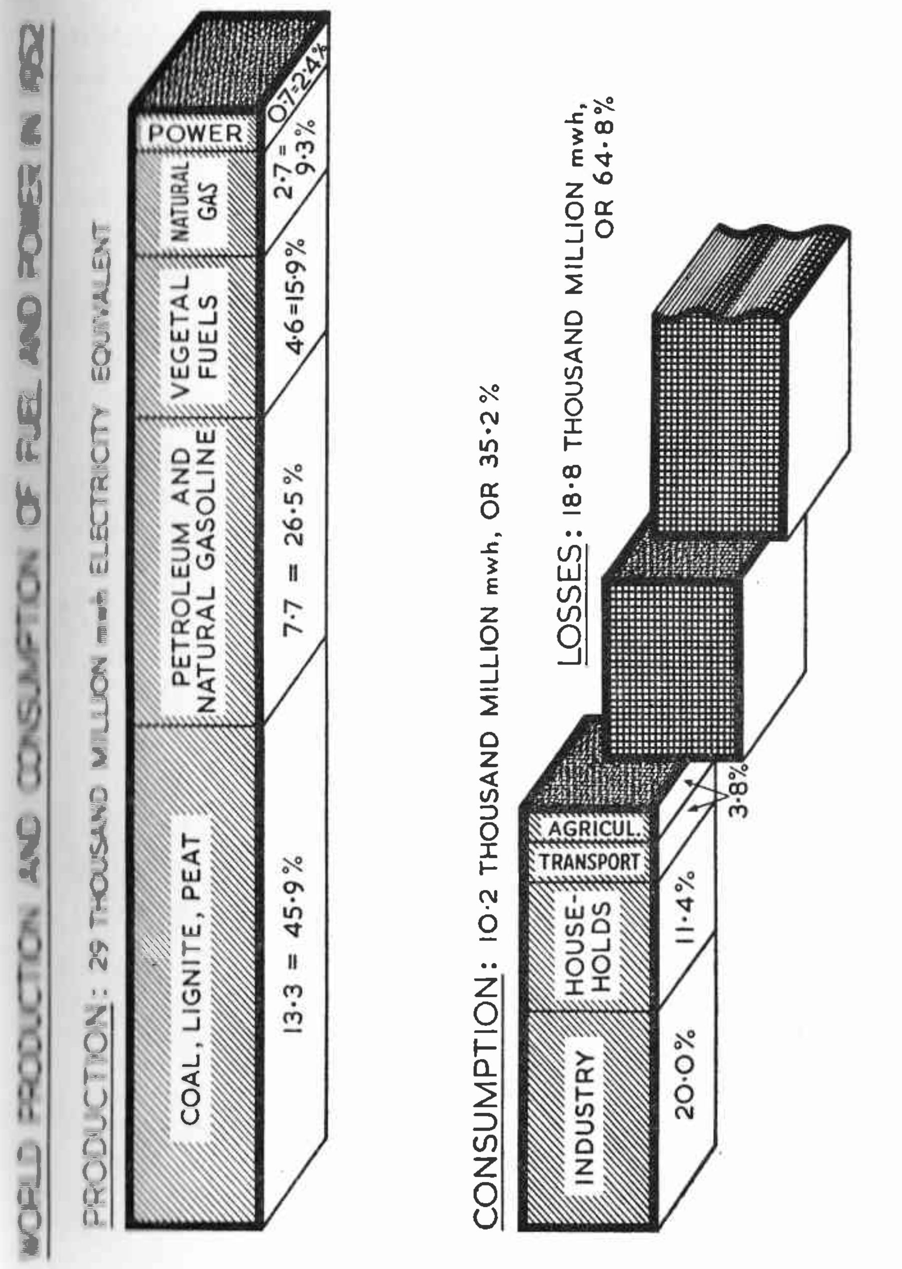
[2] The value of the megawatt-hour in other electrical units and other systems of energy measurement is as follows:

1 megawatt-hour = 1,000 kilowatt-hours (kwh)
= 1,000,000 watt-hours
= approx. 860,000 kilogram-calories (kg. cal.)
= approx. 3,412,000 British thermal units (btu)

Electricity equivalents (full theoretical energy value, in kilowatt-hours per unit indicated):

Coal	8.0 per kilogram
Brown coal and lignite	2.5 ,, ,,
Natural gas	10.6 ,, cubic metre
Petroleum	12.0 ,, kilogram

(According to Geneva Conference document P/1116, p. 5)



WORLD PRODUCTION OF FUEL AND POWER IN 1952
(quantities in thousand million mwh electricity equivalent)[1]

	Quantity	*Percentage of total*
Coal	12.0	41.4
Lignite and peat	1.3	4.5
Petroleum and natural gasoline	7.7	26.5
Natural gas	2.7	9.3
Water power	0.4	1.4
Vegetal fuels	4.6	15.9
Animate energy	0.3	1.0
Total	29.0	100.0

Of this total production of 29 thousand million megawatt-hours of electricity equivalent, however, only 10.2 thousand million, or about 35 per cent, was put to effective use, the remaining 65 per cent being lost in processing, transmission and use, or diverted to non-fuel products (lubricants, etc.). The distribution of the 10.2 thousand million megawatt-hours of *useful* heat and power was as follows:

Agriculture	0.3
Transport	0.8
Industry	5.8
Households, etc.	3.3
Total	10.2 thousand million mwh.

¶ *Approaching exhaustion of the conventional sources of energy*

Although estimates relating to the reserves of conventional energy do not always coincide, they show that those reserves are undoubtedly, even if slowly, approaching exhaustion. Confirmation of this is seen in the fact that the consumption of fuel is constantly increasing and that power requirements in the future will be very high. Palmer C. Putnam, who recently prepared a balance sheet of world energy resources on behalf of the American Atomic Energy Commission, arrives at somewhat pessimistic conclusions as to the probable duration of the

[1] Document P/902, 'World Energy Requirements in 1975 and 2000', p. 4.

conventional energy reserves.[1] He calculates that the average total consumption per century up to the year 1850 was 1 Q.[2] In the following 100 years consumption rose to 4 Q. The average annual increase in energy consumption per inhabitant of the world has been about 3 per cent since 1930 and the trend is still upwards. During the period 1900 to 1930 the average annual increase was only 2.5 per cent. On the basis of an annual increase of 3 per cent, Putnam estimates that consumption will be about 10 Q in the year 2000 and 70 Q in the year 2050. If the annual increase were 4 per cent, the volume of consumption would be 16 Q in the year 2000 and 187 Q in the year 2050.

According to estimates presented at the Geneva conference by United Nations experts, by the year 2000 the world will need at least *8 times more power* than is consumed at present. By 1975 world energy consumption will have almost trebled.[3]

Although there can obviously be no certainty in forecasts of developments in the coming half-century, we believe that energy needs will in the near future prove to be very much greater than estimated by Putnam or the United Nations experts. This appears all the more probable when account is taken of the fact that the countries of Asia, and particularly China and India which have already embarked on industrialization, will need ever increasing quantities of energy in the next few decades. It may here be noted that in the United States the per capita consumption of energy is about 10 times greater

[1] Palmer C. Putnam: *Energy in the Future*, published under contract with the U.S. Atomic Energy Commission, New York, 1953, p. 11.

[2] By 'Q', Putnam means an energy unit equivalent to the heat output of 38 thousand million tons of bituminous coal. (See *Energy in the Future*, p. 77.)

[3] Document P/902, 'World Energy Requirements in 1975 and 2000,' gives (page 48) the following table:

Potential requirements of useful energy in 1975 *and* 2000
(in thousand million mwh electricity equivalent)

	1952 (*actual*)	1975	2000
Industry	5.8	18.0	60
Transport	0.8	2.5	8
Agriculture	0.3	0.5	1
Households	3.3	6.0	15
Total	10.2	27	84

than in certain countries of Europe and 100 times greater than in certain countries of Asia. In India, in particular, the production of electric power per inhabitant is at present *80 times* less than in Great Britain, but it is estimated that it will have been multiplied by seven by 1975.

In any event, even on the basis of Putnam's conservative calculations the critical date does not appear very far distant. As regards more especially the United States—though the same remark is valid for the world as a whole—Putnam stresses the fact that if that country wishes to avoid the danger of having to pay a very high cost for its power supplies it 'must be able to find other cheap sources between now and 1975 or earlier'.[1] The United States' Materials Policy Commission, in its report for 1952, forecasts that in the near future—and in any case not later than 1975—world energy requirements will outstrip the natural resources of the conventional fuels.

The outlook so far as Western Europe is concerned is particularly disquieting. Up to 1927 Western Europe was an exporter of energy, whereas it is now becoming increasingly dependent on imported energy to cover its own requirements. According to a report prepared for the Organization for European Economic Co-operation by a group of experts, even assuming the output of coal, oil and gas is expanded to the maximum, the percentage of primary energy consumption to be provided by imports (20 per cent in 1955) will be 23 per cent in 1960 and 37 per cent in 1974.[2] One has only to think of the disruption caused by the closing of the Suez Canal in November 1956 to realize the seriousness of Europe's energy problem.

Taking consumption in 1952 as a basis, the specialist services of the United Nations estimate the probable duration of the world's reserves at 2,500 years for solid fuels (coal and lignite), and at only 32 years for natural gas. They emphasize, however,

[1] *Energy in the Future*, p. 169. In regard to the United States Putnam makes the following forecasts:

Peak production of oil gas may be reached between 1955 and 1960.
Peak production of good coking bituminous coal may be reached before 1960.
Peak production of all coal in the Eastern United States may be reached before 1975.
Peak production of all United States coal may be reached before 1990.

[2] O.E.E.C. 'Europe's Growing Needs of Energy: How can they be met?', 1956, p. 24.

the highly theoretical nature of the estimate as regards coal. There is in fact a limit to the amount of coal that can be extracted each year, for progress in extractive methods is in many cases offset by the dual fact that the seams get deeper and deeper and the manpower available for mining tends to diminish.[1]

It is clear that this situation must have an increasingly marked incidence on cost. It is interesting to note that in Western Europe prices for indigenous coal rose between 1938 and 1954 twice as fast as the cost-of-living index.[2]

From the report of the American 'Panel on the Impact of the Peaceful Uses of Atomic Energy' we reproduce the following instructive table relating to conventional fuel reserves and

POSSIBLE FUEL RESERVES AND CURRENT CONSUMPTION

	Bituminous coal (million short tons)	*Oil (billion barrels)**	*Natural gas (trillion cubic feet)**
	Total economically recoverable		
United States	950,000	120	725
Rest of free world	540,000	700	3,000
	Recoverable at present or near present costs	*Proved reserves*	*Proved reserves*
United States	237,000	35	212
Rest of free world	119,000	265	128
	1955 consumption		
United States	420	3.0	9.4
Rest of free world	1,200	2.2	0.7

*N.B.—'Billion' and 'trillion', in American usage, mean respectively 'one thousand million' and 'one million million'.

[1] This is confirmed by the report presented at the Geneva conference by E. A. G. Robinson and G. H. Daniel (U.K.), who stressed the point that the crux of the problem lies not so much in the size of the coal reserves as in the difficulty of attracting workers to coal mining. (See P/757: 'The World's Need for a New Source of Energy'.)

[2] O.E.E.C., 'Europe's Growing Needs of Energy: How can they be met?', p. 44.

showing the quantities estimated to be recoverable at or about present costs.[1]

Obviously, if the world's growing energy needs are to be met, a new source of energy has become indispensable. In his inaugural address at the Geneva conference, the President of the conference, Dr. Bhabha, remarked that present known reserves of coal and petroleum were insufficient either to permit of the attainment by the underdeveloped countries of a stable standard of living equal to that enjoyed by the most highly industrialized countries, or to assure continued economic expansion in the industrial countries.[2]

As regards the United States, which is rich in the conventional energy resources, the McKinney panel expressed the view that if the country's electric-generating capability, which had more than doubled since the end of the Second World War, continued to grow at the same rate over the next 25 years, the atomic-power capability of the United States in 1980 could be larger than the present entire electric-generating capacity.

¶ *Will nuclear power solve the energy problem?*

The extremely rapid progress now being achieved in nuclear science makes it possible to contemplate the energy problem with the greatest optimism. Indeed, the data so far made available justifies the belief that nuclear energy alone—quite apart from the other energy sources with which nature may shortly endow us—will cover the world's growing energy requirements for many centuries to come. The present stage of nuclear technique does not permit of the extraction of more than a minimal proportion of fissile material from uranium and thorium,[3] but even on that basis it is estimated that the nuclear

[1] McKinney report, p. 42.

[2] The underdeveloped countries are on the whole poor in the conventional sources of energy. According to a United Nations document (P/893) presented at the Geneva conference by M. de Beuvery, more than 80% of the world's reserves of coal are to be found in the U.S.A., the U.S.S.R., the U.K. and Germany. So far as India is concerned, Dr. Bhabha stated in the report presented by him at the conference that the known reserves of ordinary fuels would be 'insufficient to maintain for more than a couple of decades a standard of living equal to that obtaining in the industrially most advanced countries today'.

[3] At present only 1/140th part of the natural ore can be converted into fissile material.

power reserves will be sufficient for a very long period. Taking into account the economically exploitable deposits of uranium and thorium ores, Putnam arrives at the conclusion that these reserves would suffice to cover the world's energy needs for some hundreds of years.[1] In his report to the Geneva conference on the world's resources of uranium and thorium, Paul F. Kerr of Columbia University, New York, expresses the opinion that those resources are sufficient to provide a continual supply of the raw material required for the peaceful applications of atomic energy.[2] This opinion was shared by Jesse C. Johnson, Director of the Division of Raw Materials, U.S. Atomic Energy Commission, who, in his report to the conference, states that the problem of the nuclear power era will not be the availability of adequate nuclear fuels, but their efficient and economic utilization. 'There are', he says, 'adequate resources of uranium and thorium for a long range expanding world power programme'.[3] This view is in turn corroborated by the report submitted by Dr. Harrison Brown and his collaborators of the California Institute of Technology, which report remarks that the progress made in the methods of extracting uranium and thorium from *ordinary* granite justifies the belief that sufficient supplies of these two minerals will be forthcoming to cover the world's energy requirements *for four million years.*

¶ *Towards a new equivalence: 1 ton of uranium = at least 1 million tons of coal!*

Apart from the fact that new deposits of uranium and thorium will doubtless be discovered, the nuclear scientists hope that improvements in technique will eventually make it possible to transfer the whole of the mass of nuclear raw material into energy, or at least a far greater part of it than at present. It is expected that, thanks to technical developments now under

[1] According to Putnam's calculations, these deposits could yield a total of 575 Q of energy. Exploited at the rate of 35 Q per century they would be sufficient to cover energy requirements for hundreds, if not thousands, of years. (*Energy in the Future*, p. 250).

[2] See document P/1114: 'The Natural Occurrence of Uranium and Thorium'.

[3] See document P/470: 'Nuclear Fuel for the World Power Program'.

experiment (repeated re-use of the same fuel, use of power-producing breeder reactors, etc.), one ton of uranium, which in the first nuclear power stations will have a heat output equivalent to that of 10,000 tons of coal, will eventually 'do the work of at least a million tons of coal'.[1]

The progress of nuclear science is indeed so rapid that we must be prepared for spectacular results in the domain of nuclear technique and of the industrial exploitation of the atom. The leader of the British delegation at the Geneva conference, Sir John Cockcroft, said:

'The speed of development will be rapid and the nuclear power stations of 1970 will look as different from those of 1957 as the modern car differs from the model T Ford.'

If so eminent a scientist as Sir John Cockcroft affirms the possibility of such progress in nuclear science, the final solution of the world's energy problem seems certain. It must not be forgotten that at present nuclear fission disintegrates and turns into energy less than one-thousandth part of the materials used as nuclear 'fuel'.

Addressing the General Assembly of the United Nations, M. Jules Moch said:

'The total annihilation of a gramme of material—any material—would release power equivalent to that released by the burning of 20 million tons of coal. The present needs of all mankind, counted in millions of tons of coal, would thus be met by the disintegration of 300 pounds of matter.'[2]

The prospects opened up by atomic energy are thus infinite. If nuclear science continues to progress at the present rate, and if man does not divert nuclear energy from its peaceful destiny, this new source of prosperity will be practically inexhaustible.

2. WILL THE EVENTUAL HARNESSING OF HYDROGEN SUPERSEDE THE USE OF URANIUM?

These expectations, which to some may appear over optimistic, are however justified by the astounding progress already

[1] This equivalence was mentioned by Sir John Cockcroft at the Geneva conference on 19 August 1955.

[2] See *The UNESCO Courier*, Special Number No. 12, 1954, entitled 'The Promise of Atomic Power', p. 12.

achieved, while we are still only at the dawn of the atomic age. At their present rate of progress, nuclear science and technique promise us new conquests in the coming years—conquests which must ultimately revolutionize not only our material production methods but our very manner of life and thought. The day is not far distant when the nuclear fission process, which is justly regarded as the greatest scientific achievement of all time, will be eclipsed by another process of still richer promise. It seems clear that most encouraging results have already been obtained in the research and experimentation so far devoted to the production of power by means of *thermonuclear fusion.* As yet this process has been used solely for the manufacture of the hydrogen bomb. On the day when it is announced that hydrogen has been harnessed to produce power for peaceful purposes, humanity will enter upon a new phase of the atomic age: the generation of power by nuclear *fission* will have been out-dated.

¶ *The three great advantages of thermonuclear energy*

The value of this source of power resides in the three following considerations:

1. The enormous volume of energy released;
2. The low cost;
3. The elimination of radiation hazards.

A small quantity of this new nuclear fuel would satisfy power requirements which at present necessitate the use of millions of tons of coal. When fusion takes place something like 150 thousand million kilo-calories of energy is released per kilogram of hydrogen. To show the power of thermonuclear fusion, Professor V. Romadin of the Soviet Union has said[1] that:

'If a kilogramme of this nuclear fuel were placed underneath a pyramid-shaped mountain, the base of which was one kilometre square and the height of which was also one kilometre, the exploding of this fuel would project the whole mountain, weighing a thousand million tons, 65 metres into the air!'

[1] See his article, 'L'atome dompté', in *Etudes Soviétiques* of November 1954.

Apart from the fact that only a minimal quantity of fissile material is required for the process of nuclear fusion, heavy hydrogen—the primary thermonuclear fuel—is available in boundless quantities. Professor G. Petrovsky of the Soviet Union has stated that:

'If heavy hydrogen—which exists in nature and is the basic material of the H-bomb—were used to produce energy for peaceful purposes, it would furnish as much energy as could be obtained from a globe of petroleum the size of the earth!'[1]

Some conception of the vastness of this potential new source of energy can be gained by noting that, according to the same author, the known deposits of coal and petroleum represent a reserve of energy equivalent to that which could be derived from a layer of petroleum about one centimetre thick, covering the whole surface of the globe.

As to the vista opened up by the possibility of controlling thermonuclear fusion, the McKinney report remarks:[2]

'The concept of power resulting from controlled thermonuclear reaction has stimulated widespread enthusiasm because it could conceivably provide an unlimited energy resource beneficial to all people. It would use as fuel the light elements—such as hydrogen isotopes—abundantly available on the earth. In addition, most thermonuclear reactions make neutrons available. If such reactions can be sustained, neutrons captured on a large scale could lead to conversion of natural uranium and thorium into fissionable materials which could be used as energy resources.'

Once the scientists succeed in harnessing heavy hydrogen for the controlled production of energy, the cost of this energy will be so low as to be practically negligible. The reason for this is the abundance of the raw material and the simplicity of the fusion process, whereas in the case of nuclear fission two-thirds of the cost of producing electric power is accounted for by the complicated and extremely expensive procedure that has to be used to obtain the fissile material from the natural ore. This new source of energy has another great advantage: it is

[1] In an article published in a Soviet magazine and reproduced in the *Soviet Weekly* (London) of 24 February 1955.
[2] McKinney report, p. 51.

free from the radiation hazards which for the time being are a serious obstacle to the production of nuclear energy in great quantities. It would seem that with hydrogen reactors. there is no residue of lethal ash, as there is in the case of fission. In this connexion we must again quote the McKinney report:[1]

'Thermonuclear power units give promise of being extremely safe. The amount of fuel normally present within such machines would be extremely small. The possibility of a serious hazardous accident due to the failure of any component or any arbitrary mistake on the part of the operator is virtually negligible. In addition, unlike a fission reactor, there are no fission products to spread about, even in the unlikely event of an accident.'

This advantage of thermonuclear reaction is of immense importance. The ash left by nuclear fission is highly radioactive, and great efforts are still being made to discover means of eliminating this danger.

¶ *Will nuclear fusion be controlled within the next ten years?*

It is difficult to appreciate the enormous significance of this inexhaustible and almost costless source of energy. The day scientists and technicians succeed in controlling thermonuclear fusion a new revolution will have been accomplished, and the present state of knowledge about the atom will be looked back on as belonging to the 'pre-historic' phase of this new age. It would seem that that day is not far distant. In his inaugural address at the Geneva conference, the President, Dr. Bhabha, made the following striking statement :

'I venture to predict that a method will be found for liberating fusion energy in a controlled manner within the next two decades. When that happens the energy problems of the world will truly have been solved for ever, for the fuel will be as plentiful as the heavy hydrogen in the oceans.'

Another eminent scientist, the Englishman Sir John Cockcroft, although not venturing any forecast as to how soon controlled fusion would become a reality, was also optimistic. He said:[2]

[1] McKinney report, p. 52.
[2] On 19 August 1955, at the Geneva conference.

'I would like tonight to have been able to predict when the exciting prospect of power from fusion reaction would be achieved. But although we are working seriously on this problem in Britain, my vision is not good enough for that. I am not as bold as our President. The experimental physicist must inevitably have a greater appreciation of the problems and difficulties than the theoretical physicist. However, my faith in the creative ability of the scientist is so great that I am sure that this will be achieved long before it is essential for man's needs.'

While not expressing any opinion as to how long it would take, the leader of the Soviet delegation at the conference said that active efforts were being pursued in the Soviet Union to harness the energy released by nuclear fusion.[1]

It is curious to note that while nuclear fission secrets were freely revealed at Geneva, the thick veil that shrouds everything relating to 'fusion' was not lifted. No papers were presented on the subject, and it did not figure at all on the conference agenda. None the less, certain nuclear scientists broke the silence to the extent of affirming that the control of fusion would have been achieved within the next twenty years. In our opinion there is justification for anticipating that this goal will have been reached in considerably less than twenty years. If it took only about eight years to discover how to control the energy released by fission, why should it take longer to arrive at controlled fusion?[2] While not underestimating the technical difficulties still to be overcome, it appears to us that the progress already achieved in the nuclear sphere will save much time-wasting 'groping' in the new line of research.

We are strengthened in our opinion by the progress realized since the Geneva conference. Two items of information that have become available in the meantime indicate that the day when the scientists will have succeeded in harnessing thermo-

[1] Statement by the leader of the Soviet delegation, Professor D. V. Skobeltzin, at Geneva, at his press conference on 20 August 1955.

[2] The first atom bomb was exploded in the U.S.A. in August 1945. It was not until December 1951 that a small quantity (100 kwh) of usable energy was produced in that country by means of an experimental reactor. On 9 March 1953 the Atomic Energy Commission announced that 150 kwh of electricity had been produced at Oak Ridge National Laboratory from nuclear energy. In the U.S.S.R. the first atom bomb test took place in 1949 and the first nuclear power station was put into operation in June 1954.

nuclear energy for industrial use is not far distant. The first concerns the United States. On 4 April 1956 it was announced that, for the first time, controlled thermonuclear fusion had been achieved in an American laboratory and that it was believed that within ten years it would be possible to produce power for industrial use by this process. The second concerns the Soviet Union. During a visit to the British nuclear centre at Harwell, the Soviet nuclear scientist, M. Igor Kurchatov, forecast that, within a very short time, the Soviet Union would succeed in generating power by means of controlled thermonuclear fusion. Referring to this statement in its issue of November 1956, the review *Etudes Soviétiques* gave certain details, to which we shall refer later, regarding a process which appears likely to open the way to the harnessing of thermonuclear fusion for the production of power on an industrial scale.

The McKinney report, which was published four months before M. Kurchatov made the above statement, considered it 'exceedingly difficult to estimate the time-scale for the development of a controlled thermonuclear machine', but added that while it was virtually certain that no full-scale reactor would be developed in the next year or two, it was however highly probable that success would be achieved eventually. If the announcement that controlled thermonuclear reaction has now been achieved in the United States is correct, does not this mean that the Americans also are on the threshold of controlled thermonuclear power production?

The British scientists are also carrying out intensive research in this sphere. According to the *Daily Express* of 28 December 1956, they are at present constructing a machine (nicknamed 'Giant Torus') which is designed for the production of thermonuclear power for industrial use.

In the light of these various announcements, is it not reasonable to assume that the era of controlled thermonuclear fusion is near at hand? We shall, however, revert in a later chapter to the fusion problem, the solution of which will mark a decisive turning point in the industrial utilization of the atom and, indeed, in the history of the human race.

3. THE VAST POTENTIALITIES OF SOLAR ENERGY

Apart from the energy that can now be obtained from nuclear fission, and from that which will become available from thermonuclear fusion, there is an even vaster potential source of energy: the sun.

The heat given off at the sun's centre is estimated at some 25 million degrees Centigrade, of which, however, the earth receives only a minute part, the rest being lost on the 90 million mile journey. But the very small proportion which does reach us still represents an enormous amount of energy. It is calculated that in only three days our planet receives from the sun as much energy in the form of heat as could be obtained by burning up all the petroleum and gas contained in the earth and all the forests on its surface.[1] Up to the present man has been content to use solar energy 'second-hand'. Thus—to give only a few examples—by the process known as photosynthesis trees transform solar energy into wood; by evaporating sea-water, solar energy produces rain, which in turn is the primary source of hydraulic power; coal and petroleum are the transformed remains of dense forests that have laid buried for millions of years and still retain their original store of solar energy.

Research so far carried out in this sphere makes it reasonable to contemplate the possibility of the direct utilization of solar energy in a relatively near future. By an extraordinary historic coincidence, on the very day (2 December 1942) when the world's first atomic pile was operated, at Chicago in the United States, the world's first solar energy plant was brought into action, at Tashkent in the Soviet Union. By means of huge glass mirrors the sun's rays were concentrated on to boilers, which first produced superheated steam with a temperature of 463° C., and then supplied steam at 170° at a pressure of 2.1 kg. per sq. cm. In France the first experiments on the concentration of solar energy were begun in 1946 at the Meudon observatory. By means of parabolic mirrors of 2 m. diameter it was found possible to obtain a concentration of heat at the focal point reaching and even exceeding 3,000° C.

[1] Ayres and Scarlott: *Energy Sources*, New York, 1952, p. 158.

In 1949 the Meudon laboratory was transferred to Mont Louis (Pyrénées-Orientales) and its equipment was greatly amplified. Similar research is being carried out in a number of countries, and above all in the United States.

At the first International Solar Energy Congress which opened on 2 November 1955 at Phoenix in Arizona (U.S.A.), 700 scientists, from all parts of the world, reported on the results obtained in this sphere by their respective countries, and discussed the various ways in which it might be possible to put solar energy to practical use within the next few years. According to the reports submitted at this congress there are three methods of exploiting solar energy:

The *first* method consists in the direct conversion of solar energy into heat. This can be done in three ways:

(a) by the use of glass sheets mounted on a kind of box, the black internal walls of which act as a solar accumulator;

(b) by the use of mirrors which concentrate the solar rays. The temperature obtained, which may reach as much as 1,000° C., can be made to operate steam generators, low temperature furnaces and cooking appliances;

(c) by the use of parabolic mirrors of great diameter, which concentrate the heat in a recipient, the temperature of which can be raised to as high as 3,500° C. This procedure has been employed in many countries with satisfactory results.

The *second* method consists in converting the solar rays directly into electricity. This method, which is still in the experimental stage, holds out great prospects of the successful utilization of solar energy.

The *third* method converts solar energy into chemical energy by means of chemical reactions which are stimulated by light. It is this method which has been used to foster the growth of plants, and in many countries scientists are using it to study the mysteries of, and to reproduce, this natural process which is the basis of all agriculture and of the production of vegetable foodstuffs.

If the experimental work now being carried on by scientists in various countries is crowned with success, the harnessing of this new form of energy may have even more revolutionary

consequences than the advent of nuclear energy. This is what a French expert, M. Louis Armand, has to say about solar energy:

'Atomic energy is evolution—not a revolution . . . The sun may have *revolutionary effects* on our planet far greater than those produced by nuclear fission . . .'[1]

It would be outside the scope of the present book to attempt to discuss the question of the industrial exploitation of the calorific power of the sun. We would merely emphasize that there are numerous other forces, apart from atomic energy, which have not yet been exploited; in addition to solar energy there is the thermal energy of the sea; the ebb and flow of the tides; the force of the wind; the earth's temperature. All these potential sources of power could be of capital importance for future generations of mankind.

Thus, the inventory of our power potentialities is assuming a more promising aspect. Nuclear power derived from fission has already entered industrial life. Thermonuclear fusion will have been harnessed to produce utilizable power in the not distant future. Solar energy opens up boundless vistas. The attainment of the benefits that these new sources of energy could bestow depends very largely on the will of men and above all of those who govern them.

4. ENERGY A DETERMINING FACTOR IN ECONOMIC AND SOCIAL PROGRESS

In order to understand the contribution that atomic energy will make to the building of the world of tomorrow, it is first necessary to consider the part played by energy in general in economic and social progress.

It is not always realized to what extent economic development and the standard of living in every country are conditioned by the available resources of energy. Industrialization, agricultural development, transport, public health and, indeed, the level of civilization in general are all dependent on the energy factor. It is this factor in combination with technological development, that determines the growth of national income

[1] See article by Serge Groussard: 'Le monde de demain commence aujourd'hui', in *Le Figaro* (Paris), 4 May 1955. See also F. Daniels and J. A. Duffie, *Solar Energy*, 1956, and M. A. Ellison, *The Sun and its Influence*, London 1955.

and the standard of living everywhere. The following comparison between the main geographical regions of the world clearly shows this dependence, and reveals a strikingly close relationship between energy and national product:

RELATIVE DISTRIBUTION OF POPULATION, ECONOMIC OUTPUT AND ENERGY CONSUMPTION IN 1950—by regions[1]

(Percentages of world total)

	Population	*Economic output* (a)	*Energy consumption* (b)
Africa	8.2	2.6	2.7
North America	6.9	40.4	40.5
Latin America	6.8	4.4	3.7
Asia	52.7	12.9	14.1
Europe	16.5	25.8	25.8
U.S.S.R.	8.4	12.4	12.1
Oceania	0.5	1.5	1.1
WORLD	100	100	100

(a) Gross domestic product (partially estimated).
(b) Excluding energy from animate sources and bunker fuels.

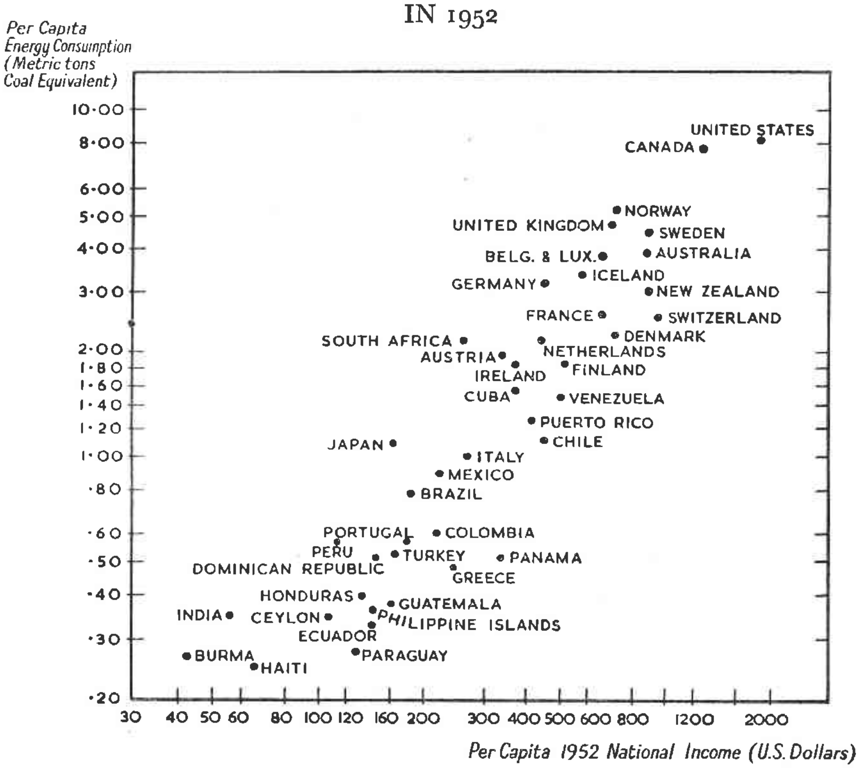
¶ *The close relationship between energy and national income*

It will be seen that those regions in which energy consumption is greatest also have the highest economic output; and, conversely, that where the output per inhabitant is very low, energy consumption is very small. North America, for example, with a population equal to only 6.9 per cent of total world population, accounts for 40.5 per cent and 40.4 per cent of world energy consumption and world economic output, respectively; whereas Asia, Africa and Latin America, which together contain two-thirds of the population of the globe, account for only one-fifth of world energy consumption and furnish barely that proportion of world economic output. On this subject Professor E. S. Mason of Harvard University has

[1] This table is taken from the report, 'Population and Energy Resources', presented at the World Population Conference (Rome, 1954) by Nathaniel B. Guyol, member of the Secretariat of the United Nations.

prepared a most instructive diagram which we reproduce below:[1]

RELATIONSHIP BETWEEN PER CAPITA INCOMES AND PER CAPITA ENERGY CONSUMPTION IN 42 COUNTRIES IN 1952



SOURCE: UN STATISTICAL OFFICE

This correlation, which clearly shows the importance of the energy factor in economic development, must, however, be interpreted with caution, account being taken of the infinite variations of structure as between the economies of different countries.

For the world as a whole, the average energy consumption per inhabitant is six times less than it is in North America.

[1] See report presented at the Geneva Conference, entitled 'Energy Requirements and Economic Growth' (P/802).

If we limit this comparison to the underdeveloped regions of the world the disparity is still more striking.

The following table shows the great variation in the annual per capita consumption of energy in a number of different countries:

PER CAPITA CONSUMPTION OF ENERGY IN 1954
(calculated in tons of coal equivalent)

United States	7.62	France	2.49
Canada	6.88	Holland	2.07
Norway	5.02	Italy	0.91
United Kingdom	4.78	Brazil	0.34
Sweden	3.76	India	0.11
Western Germany	3.03	Thailand	0.03
Switzerland	2.62	Ethiopia	0.01

Before all the countries of the world could attain the same degree of economic development as North America, it would be necessary for total world energy consumption to be raised from the present level of about 3.4 thousand million tons 'coal equivalent' to 20 thousand million.

¶ *The effect of technical progress on energy production*

It is the most highly industrialized countries which occupy the first three places in world energy consumption. Since 1830 the United States has been at the head of the list. It holds that position today with a consumption equal to 37 per cent of the world total. In 1950 Great Britain dropped back from second to third place. In that year her proportion was only 6 per cent, compared with 15 per cent in 1860. On the other hand, the Soviet Union, which in 1913 consumed only 7 per cent, moved up to second place in 1950, by which year its proportion had risen to 12 per cent. The average annual percentage increase in energy consumption per inhabitant for the period 1938–52 was 2.85 for North America, 2.0 for the United Kingdom and 3.27 for the U.S.S.R.[1]

The part played by the energy factor in the process of production bears a direct relationship to the rhythm of economic

[1] United Nations, document P/1116: 'Contribution of Nuclear Energy to Future World Power Needs.'

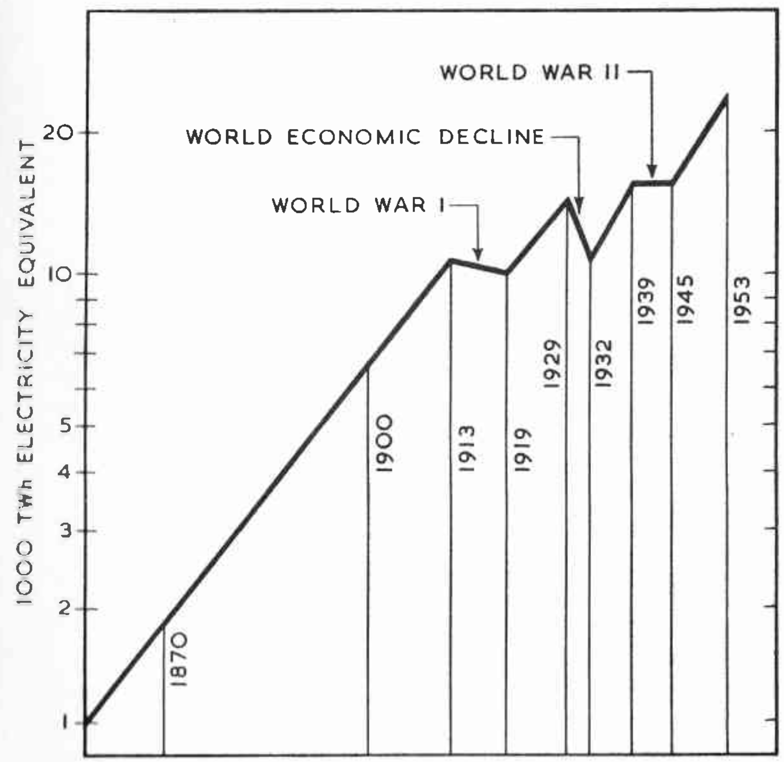
development. Thus, it is in the U.S.S.R. (where the annual increase in energy consumption is highest) that economic activity has shown the greatest annual rate of increase in recent years.

A sustained increase in the rate of economic development coincides with a growth in the consumption of energy. In the past 100 years the world has used a quantity of energy equal to half the total amount consumed in the preceding eighteen centuries of the Christian era. Moreover, during the past fifty years there has been a constant increase in the consumption of energy. From 1860 to 1900 the average annual increase per inhabitant was 2.2 per cent, for the period 1900 to 1939 it rose to 2.5 per cent, and at the present time it is around 4 per cent, with the tendency still upwards. It should further be noted that an increase in world production of energy always coincides with an upswing in economic expansion. Events like a war or an economic crisis, on the other hand, are accompanied by a fall in energy production, as is illustrated by the diagram reproduced below. This diagram, based on data contained in a document submitted at the Geneva Conference, was prepared by a group of O.E.E.C. experts.[1]

It has been calculated that energy consumption is now growing at a rate which will double it every ten years. In comparison it may be noted that the consumption figure for 1860 was not doubled until 1900. However, in order to appraise these figures at their proper value, it must be remembered that the increase in world energy consumption is not solely the result of greater gross production, but also—and more and more—of a constant improvement in productive efficiency. Productive efficiency has in fact doubled in the course of the past half century. It rose from 11 per cent to 22 per cent between 1900 and 1950. The degree of improvement has, of course, varied from country to country. In the United States the efficiency ratio trebled during those fifty years, and now stands at 30 per cent. In the Soviet Union and Great Britain the present ratio is 23 per cent, in France 20 per cent and in Germany 20 per cent. In Switzerland the ratio rose between

[1] O.E.E.C. 'Europe's Growing Needs of Energy: How can they be met?', p. 14.

RATES OF INCREASE IN THE WORLD PRODUCTION OF COMMERCIAL SOURCES OF ENERGY IN SELECTED PERIODS, 1860—1953



1900 and 1950 from 40 per cent to 58 per cent, this very high level being due to the intensive use of electric power in all sectors, particularly in traction.

It is thus thanks to the combined factors of energy and technique that the world can now produce far more than it could fifty years ago with an equal amount of labour. In this connexion we may quote the following remarks from the report of the Materials Policy Commission (U.S.A.), published in June 1952:[1]

[1] Resources of Freedom, Vol. I: Foundation for Growth and Security, p. 103.

A.U.W.—C

'With a labor force today little more than twice as big as in 1900, accompanied by more capital, better technique, but with a four-and-one-half-fold expansion in energy use, the United States economy in 1950 turned out almost *five times* the 1900 total volume of goods and services (measured in dollars of constant purchasing power).'

During the first fifty years of the present century the labour force in the United States increased by 219 per cent, energy consumption by 445 per cent, and the production of goods and services by 472 per cent. It is, therefore, easy to imagine what will be the contribution to economic progress of the vast supplies of energy that can now be released from the nucleus of the atom. It is above all in the underdeveloped countries—where, for lack of ample supplies of power, the economy is still in a primitive stage—that the utilization of atomic energy is destined to revolutionize agricultural and industrial development and to transform the nutritional and health standards of the population.

Chapter 2

FROM THE ATOM FOR WAR TO THE ATOM FOR PEACE

1. DISINTEGRATION OF THE ATOM AN ACHIEVEMENT OF UNIVERSAL SCIENCE

The disintegration of the atom and the harnessing of the energy released by nuclear fission, those great scientific conquests of the twentieth century, were the result of a truly co-operative effort, the culmination of long and patient research carried out by hundreds of scientists and thousands of specialists—engineers and technicians—of many different countries.

¶ *Democritus' atomic theory*

For the beginning of the atom story we must go back to remote antiquity. Five centuries before the beginning of the Christian era, Greek philosophers were seeking a rational and realistic explanation of the structure of the universe. For Thales, water was the beginning of all things. For Heraclitus, the basic element was fire, which constituted the motive principle in a process of perpetual evolution. For Anaximander, the cause of mutation in the natural world lay, not in some single basic element, but in the antagonism between the two states of Being and Becoming. Anaxagoras and Leucippus were the first to attempt a more materialist interpretation of the universe. According to them, all evolution was the result of the movement and interaction of an infinite number of material and indestructible substances.

It was, however, Democritus, Leucippus' pupil (born in 460 B.C.), who first formulated a clear and positive theory of the atomic structure of matter. Democritus believed that matter

was composed of minute, finite and indivisible particles which he called atoms (the Greek word ἄτομος meaning indivisible). Moving through 'empty space' (the second postulate of his theory), these atoms collided, coalesced and formed matter. The different movements, arrangements and combinations of the atoms in space determined their qualities, their modifications and their 'reunions'. Epicurus (342–270 B.C.) took the theory a step further. He held that the atom was the fundamental and indestructible germ of matter and that, whatever mutations matter might undergo, the atoms retained their stability and individuality. He sought to construct not only a philosophy of the material universe, but a philosophy of man and society.[1]

The atomism of Democritus was, however, decried by other philosophers, and above all by Aristotle (384–322 B.C.). For Aristotle, atoms did not exist: all matter resulted solely from the combination of two or more of the four primary elements—water, fire, air and earth—and was, moreover, infinitely divisible.

It was largely due to its condemnation by Aristotle and his followers that Democritus' atomic theory was to lie dormant for so many centuries. We have to wait until after the Renaissance before we find science at last shaking off the fetters of Aristotelian dogma, and meet the first real disciples of Democritus since Lucretius. An Englishman, Francis Bacon (1561–1626), an Italian, Galileo (1564–1642), and a Frenchman, Gassendi (1592–1655), were all influenced by Democritus' theory, further support for which was shortly forthcoming from the Irishman, Robert Boyle (1627–91), and from another Englishman, Isaac Newton (1642–1727). Thus, by the end of the seventeenth century Democritus' atomic theory had again found a place in the world of scientific speculation.

¶ *Einstein, new 'prophet' of atomic energy*

Before the theory received its first experimental confirmation, however, two more centuries were to elapse. During this period

[1] The atomism of Democritus and Epicurus was revived and expounded by the Roman poet Lucretius in his 'De natura rerum' ('On the Nature of Things'), written about 60 B.C.

it was further consolidated by such scientists—to mention only the most outstanding names—as the Frenchman Lavoisier, the German Richter, the Englishman Dalton, the Italian Avogadro, the Swede Berzelius and the Englishman Faraday.

In 1905 a new 'prophet' of atomic energy appeared. Albert Einstein was already known as a brilliant mathematician, but the world had still to learn the full measure of his genius. When studying the velocity of light and the mass of an electron in motion, Einstein formulated an equation that was destined to revolutionize scientific thought and to provide the key which, 37 years later, released the energy contained in the nucleus of the atom.

What was the meaning of this famous equation of Einstein—$E = mc^2$?[1] The theory prevailing at that time was based on two laws: that of the conservation of mass and that of the conservation of energy. According to this concept, neither matter nor energy could be either created or destroyed. Einstein rejected this theory, asserting that mass and energy were interchangeable, that neither matter nor energy was indestructible, and that the one could be converted into the other. By the destruction of a minute quantity of matter, a formidable quantity of energy could be obtained. According to Einstein, the energy released must equal the mass multiplied by the square of the enormous velocity of light. Thus, the destruction of a mass 'm' will produce energy 'E'. The quantity of the energy liberated will be found by multiplying the mass 'm' by the square of the velocity of light, that velocity being expressed in centimetres per second (represented in the equation by the symbol 'c'). This equation embodies the essence of Einstein's theory of relativity. In the last analysis, energy and mass are identical. In other words, mass—that is to say, matter—is only a form of energy, and there is a simple relation between the mass of a body and the energy contained in it. According to Einstein's equation, if one gram of matter could be completely disintegrated, it would produce 25 million kilowatt-hours of energy, equivalent to a constant output of 1,000 h.p. over a period of four years.

[1] A. Einstein: *Out of My Later Years*, London, 1950, p. 49.

Einstein's sensational discovery was received with some scepticism. Formalist mathematicians regarded his figures with suspicion, and at that time there was no known way of putting his theory to the test. The accuracy of this great scientist's calculations was unfortunately to be demonstrated in a tragic manner—by the explosion of the Hiroshima bomb in August 1945. The power of this first atomic bomb was in fact equivalent to the energy produced by the disintegration of a *single* gram of matter.

The English physicist, J. G. Feinberg, draws a vivid parallel between the atomic concepts of Democritus and Einstein. He writes:[1]

'There was Einstein, back in 1905, with nothing but a pencil, a piece of paper and his brain, years before anyone had succeeded in smashing an atom and destroying matter, predicting that matter *could* be destroyed and that when it was destroyed it would produce terrific quantities of energy.

'And there was Democritus, in the fifth century B.C., with nothing but a stylus, a tablet and *his* brain, centuries before science had learnt how to explore within a substance, predicting that all substance was made up of atoms.'

Without underestimating the work of the innumerable scientists and technicians who, by their persistent efforts since 1905, have made possible this staggering advance in nuclear physics, we must regard Democritus and Einstein as the 'fathers' of the atomic theory. Democritus was the precursor of the modern atomists, while Einstein pointed out the path that was to lead to the atomic age. Let us hope that the course of history will be such that in a not too distant future it may be possible to erect statues to these two great men before the portal of an international atomic energy organization, in token of humanity's gratitude for the benefits bestowed upon the world by this new source of power.

¶ *Birth of the atomic age*

The scientific atmosphere of the first half of the twentieth century was propitious to that development of the theories of

[1] *The Atom Story*, p. 13.

Democritus and Einstein which was to culminate in the birth of the atomic age. This scientific revolution could not, in fact, have come about but for the cumulative achievement of eminent scientists working in a number of different countries. Following the discovery of X-rays by the German, Röntgen, in 1895, of 'natural' radioactivity by the Frenchman, Becquerel, in 1896, and of radium by Pierre and Marie Curie in 1898, the Dane, Niels Bohr, established in 1913 the modern theory of the atom. On the basis of the quantum theory propounded by the German, Planck, and of the atomic model elaborated by the Englishman, Rutherford, Bohr succeeded in demonstrating the stability of the chemical properties of atoms. In 1919 Rutherford and another Englishman, Soddy, achieved the first artificial atomic transmutation and thereby gave new impetus to the study of nuclear reactions. Their achievement had shown that it would, in principle, be possible to turn mercury into gold, for example, and thus translate into reality the dream of the ancient alchemists. In 1924 the Frenchman, Louis de Broglie, laid the foundation of wave-mechanics by his theory on the undulatory movement of electrons. In 1929 Lawrence, of California, invented the cyclotron. In 1932 two Englishmen, Cockcroft and Walton, demonstrated experimentally the truth of Einstein's theory of the equivalence of mass and energy, and Chadwick, also an Englishman, identified the neutron as one of the fundamental constituents of the atomic nucleus. In 1934 Frédéric and Irène Joliot-Curie, of France, discovered 'artificial' radioactivity and provided chemical proof of the reality of nuclear transmutations. Their creation of radioactive isotopes placed invaluable material at the disposal of specialists in numerous branches of research. In acknowledging the award to him of the Nobel Prize in 1935, Frédéric Joliot-Curie predicted in the following words the gigantic new force with which atomic energy would one day furnish humanity:

'If we turn to the past and glance at the progress achieved by science at an ever-increasing rate, we are right in thinking that research workers, synthesizing or splitting elements at will, would produce a transmutation of an explosive character, a veritable chemical chain-reaction. If such a transmutation

could be carried out with matter, one could imagine the enormous liberation of utilizable energy which could ensue.'

Neutrons were used to bombard atomic nuclei for the first time by the Italian, Enrico Fermi, in 1934. At about the same period the discovery of other primary particles, such as the positive electron and the meson by the Japanese, Yukawa, together with the results of research in the field of cosmic radiation, greatly contributed to the advancement of nuclear physics. In 1938 the Germans, Hahn and Strassmann, established that, when bombarded with neutrons, the uranium nucleus splits into two parts of roughly equal size. In 1939 experiments by Frédéric Joliot-Curie and the German, Frisch, showed that when a uranium atom fissures, it emits several neutrons. Finally, as already mentioned, on 2 December 1942 Enrico Fermi, who on leaving Italy had continued his nuclear research at the University of Chicago, succeeded with his collaborators in putting into operation the world's first chain-reacting pile and releasing, for a short period, a very small quantity of atomic energy, equivalent to a power level of ½ watt.

We have so far mentioned only the work of the 'western' scientists, for information is not available as to the course of development of nuclear research in the Soviet world. The fact, however, that the Russians, also, have succeeded in releasing atomic energy proves that parallel progress has been made by them in this domain. It became evident at the Geneva conference that as early as 1939 Soviet physicists already possessed all the knowledge necessary for the production of nuclear fission.

2. THE ATOM IN THE SERVICE OF WAR

It was not until nearly three years after Fermi's first atomic pile test that the release of nuclear energy on a massive scale was achieved. On 16 July 1945, the first atomic bomb, which had been constructed in the laboratory at Los Alamos, New Mexico, under the direction of J. R. Oppenheimer, was detonated at Alamogordo. On that day the nuclear scientists saw their long and untiring labours crowned with success. But it was only after the explosion of the atom bomb at Hiroshima on 6 August 1945 that the world as a whole learned of

the terrifying power of the atom. This is how an official report describes what happened when the bomb exploded:[1]

'At the time of the explosion energy was given off in the forms of light, heat, radiation and pressure. The complete band of radiations, from X and gamma rays, through ultra-violet and light rays to the radiant heat of infra-red rays, travelled with the speed of light. The shock wave, created by the enormous pressure, built up almost instantaneously at the point of the explosion but moved out more slowly, that is at about the speed of sound.'

Announcing this historic event to the world some hours later, President Truman said: 'That bomb had more power than 20,000 tons of T.N.T.' This meant that, to have obtained an equal effect with ordinary bombs, at least one thousand heavy bombers would have been needed to carry them. The immensity of the disaster caused by the two atom bombs exploded over Japan was such, says one British report, that all urban and industrial life was completely paralysed. The victims of these two bombs totalled 130,000 killed and 70,000 injured.

It is regrettable that history must record that this gigantic new source of energy first revealed itself to the world as an instrument of devastation and death, or, in the words of J. R. Oppenheimer, as a 'weapon of aggression, surprise and terror'. History will judge whether this murderous use of nuclear energy was necessary, or whether atomic explosions should not have been confined to scientific experimentation. It must here be stressed that a majority of the scientists engaged in nuclear research at that time were opposed to the use of the atom bomb as a means of destruction. Some days before the first experimental explosion at Alamogordo, a secret consultation showed that of the scientists at the Chicago Laboratory only 15 per cent. were in favour of the use of the bomb as a military weapon.[2] Moreover, after the war had ended nuclear scientists, grouped in an 'association', warned the general public of the gravity of the situation that would be created by further development of the bomb, and declared that the primary object of their

[1] United States Strategic Bombing Survey: Summary Report (Pacific War). (U.S.S.B.S. 4, p. 22.)

[2] Bulletin of the Atomic Scientists, February 1948, p. 44.

association was to promote the application of atomic energy to peaceful uses by means of an international agreement.

¶ *Entry of the atom into history precipitated by military motives*

It is equally regrettable to have to admit that this gigantic new force would not have been released so soon had not military exigencies precipitated its appearance.

It is true that towards the middle of 1939 the nuclear scientists were at grips with the final problems whose solution would make possible the release of nuclear energy. The discoveries made between 1932 and 1939 had brought them very near to the stage at which it would be possible to harness the energy contained in the uranium nucleus; but many problems of a technical nature still remained to be solved, and for their solution immense material resources were required. That the funds for the huge expenditure involved were so promptly made available was due to the fact that nuclear science had been mobilized in the service of war. It is discouraging to note, on the one hand, the alacrity with which governments devote fabulous sums to the production of weapons of destruction for the purpose of achieving military supremacy and, on the other hand, the niggardliness they display when it is a question of measures to promote social progress and well-being.

Although nuclear research was European in origin, and had remained so down to 1939, it was in the United States that nuclear energy was first released and the first atom bomb produced. The explanation is that numerous eminent physicists, driven from their European homelands under the Hitler and Mussolini régimes, had taken refuge in the United States, where they had been enabled to continue their research work. The final, supreme effort to achieve the release of nuclear energy was due to a letter addressed by Albert Einstein to President Roosevelt on 2 August 1939. Fearing that Hitler-Germany might be first with the atom bomb—a weapon which might well enable that country to win the war that was then so clearly impending—Einstein decided, in agreement with a group of other scientists, to write this letter, of which the following is the principal passage:

'In the course of the last four months it has been made probable through the work of Joliot in France, as well as Fermi and Szilard in America, that it may become possible to set up a nuclear chain reaction in a large mass of uranium, by which vast amounts of power and large quantities of new radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

'This new phenomenon would also lead to the construction of bombs, and it is conceivable—though much less certain—that extremely powerful bombs of a new type may thus be constructed.'

This document was the decisive factor in the launching of the American atomic energy programme. It led to the putting into operation of the first atomic pile, on 2 December 1942, after which work was immediately begun on the construction of immense factories for the large-scale production of the 'fissile' materials required for the manufacture of atom bombs.

¶ *The atomic armaments race between the two blocs*

Since 1946 every effort has been concentrated on the manufacture of atomic weapons. This armaments race entered a new phase from the moment when, in 1949, the Soviet Union exploded its first atom bomb. In response to this development, President Truman announced on 31 January 1950 that he had given orders for work to begin on the production of a thermonuclear bomb (the hydrogen bomb), a weapon that would be far more powerful than the atom bomb. In 1953 the Americans tested their first thermonuclear bomb—and, only a few months later, the Russians exploded theirs. Nuclear 'fission' had thus been succeeded by the one to two thousand times more powerful thermonuclear 'fusion'. In 1954 both sides carried out further H-bomb tests.

The view then prevailing was that manufacture of the bombs was the only guarantee of survival in an eventual international conflict. This is how this policy was described in 1953 by Gordon Dean, on whom, as President of the American Atomic Energy Commission from 1950 to 1953, had rested the

highest responsibility for the execution of the atomic energy development programme:[1]

'At the end of the long, bustling atomic energy production line, with its far-flung exploration parties, remote mines, futuristic plants, and booming construction activity, lie the secret locations where our national pile of atomic weapons is stored. These weapons are the end product. *They are what all the activity is about and what the production line is for.*[2] By merely reposing in their hidden vaults they affect the lives of all of us and influence the course of world events.'

This 'military' orientation of atomic energy has resulted in a general delay in its exploitation for industrial purposes, and has created an atmosphere of apprehension. The peoples of the world, and above all those of the underdeveloped regions, have seen with anxiety the priority given to the destructive potentialities of the atom. The repeated tests of nuclear and thermonuclear bombs have alarmed public opinion and rendered any long-range reconstruction plan illusory. The politicians of the two blocs and the men of science have constantly warned us of the dangers which menace us, thereby stifling any optimism as to the future. The world has thus seemed to be entering a hopeless impasse. In its issue of 1 January 1955 the American journal, *Time*, painted a sombre picture of the situation:

'. . . Now the world is only a few steps (perhaps four or five years) away from absolute atomic deadlock, the point where the U.S. and the U.S.S.R. could destroy each other in all-out war, no matter which held a slight advantage and no matter which shot first.'

Thus, the conquest of the atom, achieved after a long, patient and finally triumphant struggle by man with nature, ends in a nightmare!

3. TOWARDS THE PEACEFUL USE OF ATOMIC ENERGY

The history of science teaches us:

First: that no scientific monopoly can be lasting, and

Secondly: that every invention whose original purpose is destructive very soon reveals a creative and beneficent potentiality.

[1] *Report on the Atom*, p. 103.
[2] Our italics.

The truth of these two statements has been confirmed by a series of events in the past few years.

¶ *End of the monopoly of nuclear power*

The fact that the Soviet Union also succeeded in releasing nuclear energy and produced the atom bomb in 1949 and the hydrogen bomb in 1953 is a decisive factor in international policy. It has shown in the first place that there is no longer any atomic 'secret' and that nuclear weapons not only do not provide any nation with the slightest security, but can only lead to war.

It is a mistake to believe that any one country can maintain indefinitely a monopoly of scientific knowledge. Gordon Dean remarks that 'the atom knows no nationality, race or ideology', and adds:[1]

'The secret that has been learned by one may be learned by another. It takes brains, knowledge, skill and resources, but these are not the exclusive possession of any one nation or any one group of nations.'

By a realistic speech delivered before the General Assembly of the United Nations on 8 December 1953, the President of the United States, Mr. Eisenhower, gave a new orientation to American atomic policy. After stating that the United States no longer held a monopoly of atomic power, and that the expenditure of vast sums for weapons and systems of defence gave no nation a guarantee of absolute safety, he added: 'It is not enough just to take this (atomic) weapon out of the hands of the soldiers. It must be put into the hands of those who will know how to strip its military casing and adapt it to the arts of peace.' In proposing the constitution of an international atomic energy agency, under the aegis of the United Nations, to organize the peaceful use of atomic energy, President Eisenhower said:

'The United States knows that if the fearful trend of atomic

[1] *Report on the Atom*, p. 216.

military build-up can be reversed, this greatest of destructive forces can be developed into a great boon, for the benefit of all mankind. The United States knows that peaceful power from atomic energy is no dream of the future. That capability, already proved, is here—now—today. Who can doubt, if the entire body of the world's scientists and engineers had adequate amounts of fissionable material with which to test and develop their ideas, that this capability would rapidly be transformed into universal, efficient, and economic usage?'

This speech by the President of the United States raised new hope in all countries: it provided the basis for a new international policy, which has since been assuming an increasingly tangible form.

The second event that accelerated the re-direction of atomic policy towards the industrial sphere was the putting into operation in the Soviet Union, on 27 June 1954, of the world's first nuclear power station, with an output capacity of 5,000 kilowatts.

¶ *Role of the scientists and of public opinion*

Two other factors have greatly contributed to the emergence of this new international policy: the courageous attitude of nuclear physicists and of scientists in general, and the revulsion of a very large part of public opinion against the destructive aspect of atomic energy.

From the outset, and without ever changing their view, the atomic scientists saw in this new force only its creative and constructive potentialities. As we have already said, it was with anguish that they felt obliged to devote their primary efforts to the service of military aims. When the war had ended, nuclear scientists, grouped together in an association, warned public opinion of the gravity of the situation that would be created by the further development of the bomb, and declared that the primary aim of their association was to promote the use of nuclear energy for peaceful purposes. Eminent scientists who played a leading part in the releasing of atomic energy have openly protested against the manufacture of new weapons of

mass destruction and called on fellow scientists to use their influence to safeguard world peace and security. In a message addressed to the intellectuals of the world in August 1948, Albert Einstein said:[1]

'We scientists, whose tragic destiny it has been to help in making the methods of annihilation more gruesome and more effective, must consider it our solemn and transcendent duty to do all in our power to prevent these weapons from being used for the brutal purpose for which they were invented . . . We must build spiritual and scientific bridges linking the nations of the world. We must overcome the horrid obstacles of national frontiers . . .'

In the last few years men of science have uttered grave warnings of the dangers inherent in the atomic armaments race. Two recent declarations, in particular, signed by scientists of world-wide repute, have deeply impressed public opinion everywhere. The first of these, presented by Lord (Bertrand) Russell to the British Prime Minister on 9 July 1955, on the eve of the Conference of the Big Four at Geneva, was signed by nine eminent scientists, including Albert Einstein. It called upon men of science and public opinion throughout the world to endorse the following appeal:[2]

'In view of the fact that in any future world war nuclear weapons will certainly be employed, and that such weapons threaten the continued existence of mankind, we urge the governments of the world to realize, and to acknowledge publicly, that their purposes cannot be furthered by a world

[1] *Out of My Later Years*, p. 154.

[2] This declaration was signed by Professor P. W. Bridgman, Nobel Prize winner in physics (Harvard University, U.S.A.); Albert Einstein, Nobel Prize winner in physics (the great scientist signed the declaration a week before his death); Professor Leopold Infeld, Member of the Polish Academy of Science (University of Warsaw); Professor Frédéric Joliot-Curie, Nobel Prize winner in chemistry, professor at the Collège de France; Professor H. J. Muller, Nobel Prize winner in physiology and medicine (University of Indiana, U.S.A.); Professor C. F. Powell, Nobel Prize winner in physics (University of Bristol, Great Britain); Professor J. Rotblat (University of London); Bertrand Russell, Nobel Prize winner in literature; Professor Hideki Yukawa, Nobel Prize winner in physics (University of Tokyo).

Professors Joliot-Curie and Muller signed the declaration, while expressing certain reservations.

war, and we urge them, consequently, to find peaceful means for the settlement of all matters of dispute between them.'

The second appeal was issued a few days later over the signatures of eighteen Nobel prize winners.[1] It said that all nations must come to the decision freely to abandon force as the last resort of policy: if they were not ready to do this, they would cease to exist. The statement contained the following warning:

'. . . We see with horror that this very science is giving mankind the means to destroy itself. By total military use of weapons feasible today, the earth can be contaminated with radio-activity to such an extent that whole peoples can be annihilated. Neutrals may die thus as well as belligerents.

'If war broke out among the great powers, who could guarantee that it would not develop into a deadly conflict?'

The growing pressure of *public opinion* has found concrete expression in a number of ways. Mention may be made in particular of the various appeals and conferences of the World Council of Peace,[2] the exhortations of Pius XII and of dignitaries of the Greek Orthodox Church, and messages from the protestant churches.

All this has contributed to the creation of an atmosphere of *détente*, an atmosphere which made possible the unanimous adoption by the United Nations, on 4 December 1954, of an important resolution, which:

(a) expressed the hope that an international atomic energy agency would be established without delay; and

(b) invited all members of the United Nations Organization and its specialized agencies to take part in a scientific conference, to be held not later than August 1955, 'to explore the means of developing the peaceful uses of atomic energy through international co-operation.'

[1] This appeal was signed by Hideki Yukawa (Japan); Arthur H. Compton, Fritz Lippman, H. J. Muller and W. M. Stanley (United States); Otto Hahn, Adolf Butenandt, Gerhard Domagk, Werner Heisenberg, Richard Kuhn, Hermann Staudinger and Kurt Adler (Germany); H. K. A. S. von Euler and Georg von Hevesy (Sweden); Paul Müller and L. Ruzicka (Switzerland); and Max Born and Frederick Soddy (Great Britain).

[2] According to statements in the public press, the number of signatures collected for the 'Vienna Appeal' amounted in September 1955 to 655 million.

4. IMPORTANCE OF THE GENEVA CONFERENCE ON THE PEACEFUL USES OF ATOMIC ENERGY

Ten years after the dramatic appearance of nuclear power, 1,400 delegates—scientists and experts—representing 73 countries met in conference at Geneva, from 8 to 20 August 1955, 'to explore the means of developing the peaceful uses of atomic energy through international co-operation.' This Conference, on which great hopes were placed by all peoples and which assembled with the good wishes of the governments of the great powers, was undoubtedly a success.[1] At its closing session, the President of the Conference, Dr. Homi Bhabha said: 'It is the unanimous view of all concerned that this Conference has succeeded beyond all hopes and expectations.'

It should be recognized that this success was facilitated by the atmosphere of mutual understanding created at the conference of the 'Big Four' which took place at Geneva a few weeks previously.

In the course of the Geneva Atomic Conference, at which more than 1,000 scientific papers were submitted, the various aspects of the nuclear problem were examined. It is clearly impossible for us to give here even a cursory summary of the proceedings of the conference,[2] nor is it within our purpose to

[1] At its opening session the Conference listened to speeches by M. Max Petitpierre, President of the Swiss Confederation, and Mr. Dag Hammarskjöld, Secretary-General of the United Nations, and to messages sent by President Eisenhower, Marshal Bulganin, Sir Anthony Eden, M. Edgar Faure and Mr. Nehru. Speeches and messages all stressed the importance of the Conference and the hope that it would foster international co-operation in an ever-widening utilization of atomic energy for peaceful purposes.

[2] The proceedings of the Conference were published early in 1956 in 16 volumes, in separate English, French, Russian and Spanish editions. The titles are as follows:

Volume 1. 'The World's Requirements for Energy: The Role of Nuclear Power'
2. 'Physics; Research Reactors'
3. 'Power Reactors'
4. 'Cross-Sections Important to Reactor Design'
5. 'Physics of Reactor Design'
6. 'Geology of Uranium and Thorium'
7. 'Nuclear Chemistry and the Effects of Irradiation'
8. 'Production Technology of the Materials Used for Nuclear Energy'
9. 'Reactor Technology and Chemical Processing'
10. 'Radioactive Isotopes and Nuclear Radiations in Medicine'
11. 'Biological Effects of Radiations'

do so. What we desire to do is to draw attention to certain facts which emerge from the conference papers and discussions —facts which in our opinion reflect the new orientation of atomic policy.

a. *The atom for peace.* By the rich documentation which it has made available, the Geneva Atomic Conference has explained to the world how this new source of energy can assist economic development and help to raise the standard of living, and how radioactive isotopes can serve a wide variety of purposes in agriculture, industry, medicine and biochemistry. In a word, the Geneva conference has 'rehabilitated' the atom and has 'prophesied' that an era of prosperity hitherto undreamed of could rapidly be brought about if the world were, with one accord, to determine that atomic energy should be used for no other purposes than to further the works of peace.

b. *The atom in industry.* The Geneva conference has shown that the commercial use of atomic energy is not a dream but a present reality, that within a few years the first nuclear power stations will be supplying electricity to industry, agriculture and transport in ever growing quantity, and that, in the matter of production cost, this new source of power is already competitive with the traditional sources.

c. *The atom as a factor in world trade.* The conference has shown that the larger nations are prepared to supply other countries, and particularly the underdeveloped countries, with nuclear reactors, radioisotopes and other atomic equipment and material. This offer 'internationalizes' the benefits of the atom and inaugurates among the 'atomic countries' a new branch of competitive trade which cannot fail to benefit the less well endowed nations of the world.

d. *The end of atomic secrecy.* The papers presented at the con-

12. 'Radioactive Isotopes and Ionizing Radiations in Agriculture, Physiology and Biochemistry'
13. 'Legal, Administrative, Health and Safety Aspects of Large-Scale Use of Nuclear Energy'
14. 'General Aspects of the Use of Radioactive Isotopes; Dosimetry'
15. 'Applications of Radioactive Isotopes and Fission Products in Research and Industry'
16. Record of the Conference.

ference showed that scientists in different parts of the world had arrived at almost identical results although they had been working quite separately. A press communiqué of 11 August 1955 regarding the session devoted to the physics of nuclear fission contained the following statement:

'Physicists from the Soviet Union, the United Kingdom and the United States were in almost complete agreement today on an important point of atomic technology. Comparing measurements of one of the basic quantities in atomic energy, they found that all had arrived at practically the same result.

'. . . The number of neutrons emitted per fission has to be known for any use of atomic energy. And the greater the accuracy with which it is known, the more efficiently the energy can be used. The most accurate measurements of this number yet made were reported by R. B. Leachman of the U.S., by M. S. Kozodaev of the U.S.S.R. and by J. E. Sanders of the U.K. The measurements arrived at in all three countries were practically similar.'

At the Geneva conference it became clear that the 'secrets' of nuclear fission were henceforth accessible to all countries of the world, not only on the purely theoretical plane but also for practical laboratory work.

e. *Scientific co-operation.* One of the most important aspects of the conference was that it 're-established a means of communication between men of science'. Scientists from all over the world met together to report upon and discuss their work in a spirit of cordial mutual understanding. This re-establishment of contact in the scientific world is of immense significance for the future progress of nuclear science. Collaboration among scientists is all the more necessary since, according to what the specialists tell us, the nucleus of the atom still retains many of its secrets. The physicists may have achieved some understanding of the structure of atoms; but they have not yet succeeded in really 'smashing' a single one: so far they have not been able to do more than 'chip' them, as Gordon Dean remarks. An enormous amount of research has indeed still to be done before nature discloses its nuclear secrets and, as Louis de Broglie has aptly said: 'Each new advance in our knowledge sets more

problems than it solves, and in this domain each newly discovered country reveals the existence of immense continents still to be explored.'[1]

f. *The 'nationalization' of science.* The very rapid progress of nuclear science since 1940 would not have been achieved had not almost unlimited material means been placed at the disposal of the atomic scientists. According to the data so far available—information about the Soviet Union is lacking—up to 1954 the United States had spent 16 milliard dollars on its atomic programme. It is thus clear that science has reached a stage at which further development will call for material resources so considerable that neither the scientists, nor scientific institutions, nor even the largest private enterprises, will be capable of supplying them.

Under the competitive system that functioned in the era of economic liberalism, private enterprises were able to utilize new inventions and thereby promote scientific progress. That era has passed. The economic structure has radically changed, and private enterprises, even if it were in their interest to do so, could not shoulder the enormous cost that scientific development now entails.

Further, it is only by large-scale and often prolonged experimentation, unhampered by considerations of finance, that it is possible to overcome the great technical difficulties inherent in each new process. When, for instance, the American atomic experts were instructed to apply themselves to the manufacture of the H-bomb, they had to construct an installation which cost no less than 13 thousand million dollars! In the event, that installation was never used, an extraordinary simplification having in the meantime eliminated all difficulties and made it possible to produce the thermonuclear bomb relatively 'cheaply'. But this 'simplification' would certainly not have been hit upon had it not been for the vast sums expended on previous research.

Henceforth, only the State will be capable of bearing the enormous cost of the research that will be indispensable for the progress of nuclear physics and of science in general. Scientific research thus becomes a *public service* of capital importance to the future of every country. In order that its results may promote the well-being of the community as a whole, scientific research must be co-ordinated under a general plan. The independence and autonomy formerly enjoyed by science are no longer conceivable. Experience has shown that the countries in which scientific research is abundantly endowed and rationally organized are those which have attained the highest level of economic development and the most marked improvement in living standards. This organization and co-ordination must, however, leave the individual scientist absolute freedom within his particular field of research: team-work and planning must neither lessen the responsibility of the scientist nor fetter his individuality.

[1] Lecture delivered at the Musée Guimet on 28 February 1955.

Although the Geneva Atomic Conference made a contribution of capital importance to the further development of nuclear science,[1] it is not without interest to note that a number of vital problems were not touched upon at the conference. Among these must be mentioned:

1. The economic and social repercussions of the new discoveries;
2. The banning of the use of atomic energy as a weapon of war;
3. Submarine and aerial propulsion techniques;
4. The progress of research concerning the *harnessing of thermonuclear fusion.*
5. The constitution of the 'international atomic energy agency' proposed by President Eisenhower.

Since the Geneva conference, however, great progress has been made with regard to certain of the problems which did not figure on the conference agenda. Mention should be made in particular of the unanimous decision of the Assembly of the United Nations to create the International Atomic Energy Agency, which is to begin to function on 1 January 1960.

[1] A series of articles on the proceedings of the Geneva Conference was published in the *Bulletin of Atomic Scientists*, October 1955.

Chapter 3

COMPETITION BETWEEN THE TWO BLOCS A FACTOR OF PROGRESS

I. THE DIVISION OF THE WORLD INTO TWO OPPOSING SYSTEMS FOSTERS TECHNICAL DEVELOPMENT

The peaceful use of atomic energy will—as we shall see in detail in the following chapters—have repercussions of a *revolutionary* character in the economic, social and political spheres. The world will assume a new aspect and the present antagonisms will fade little by little in face of this perpetual tendency towards uniformity, towards unity.

If we wish to grasp the significance of this scientific and technical revolution and to assess its probable repercussions, we must not try to do so by making comparisons with the past. This revolution will not resemble any that have preceded it and its consequences will be of an entirely different nature; for it comes at a moment in history when economic, social and political conditions are in no way comparable with those of the past. It is precisely this fact which, on the one hand, will hasten the exploitation of this great discovery and, on the other, will tend to make the repercussions of such exploitation wider, deeper and more violent.

Formerly world economy was based on a single social system; there was one world market; the world was not divided into 'blocs'; large private enterprises were able to avail themselves of new inventions; a large part of the world was living in a state of colonial subjection and these peoples had no say in the matter of the exploitation of their own national resources. Today, everything has changed. The world is divided into two blocs, which have different and conflicting economic systems.

a new form of economic life has spread over a large part of the globe, embracing 38 per cent of the world's total population. The world market has been split into two. The former subject races, having for the most part obtained their independence, are seeking in every possible way to develop their economies in order to raise their extremely low standards of life. Finally, economic planning is daily becoming more and more of a necessity.

Each of the two opposing blocs is endeavouring, by every possible means, to show that its system is superior to that of the other bloc and, to this end, is mobilizing every resource of science and technology. In this competition every new progress achieved is of the first importance. On the assumption that another world war is unthinkable in this atomic age, the struggle between the two blocs must necessarily take place on the *economic* plane. In this rivalry the bloc that makes the most rapid and most effective use of atomic energy will derive the greatest advantages from this race for supremacy. This is a point which must be taken into consideration if it is desired to assess the benefits which this new source of energy will confer on nations and individuals. That this new technical discovery has already become a factor in world trade, and will play an increasingly prominent role in determining its structure and development is seen in the fact that the leading 'atomic countries' are already competing for orders from the non-atomic countries for nuclear reactors and fissile materials.

¶ *Competition between the two blocs favours scientific progress*

Can it be asserted that the division of the world into two opposing blocs is a factor making for technical and scientific progress? We believe that it can. In fact, it is precisely because the world is thus divided, and because of the rivalry that exists between its two sub-divisions, that we are passing from the atom-for-war to the atom-for-peace and that we have been able to attain the present stage of industrial exploitation of nuclear fission. If the economies of all countries of the world were still based on the system of private enterprise, it is improbable that the atom would have made its entry into industrial

life by now. There would as yet have been no nuclear power stations in operation. This statement should surprise no one who understands the spirit and logic of that system. In the days when free competition still existed in all countries, the entrepreneur tried to eliminate his competitor by exploiting to his own profit every new advance in technology, the benefits of which were thus passed on to consumers. The growth of monopolies, however, has tended to delay the utilization of new technical discoveries and inventions, out of fear that they would render existing installations obsolete or, in other words, deprive previous capital investment of some or even all of its value.

Such an attitude is all the more comprehensible when it is a question of the adoption, not of some relatively minor technical improvement, but of an entirely new source of power of so revolutionary a nature as atomic energy. It is thus not surprising to note that in the early days of the atomic era certain circles in the United States were perturbed at the possibility of too rapid an entry of the atom into industry. Arguments were advanced—particularly during the first years of this new era—that are characteristic of this attitude. Some people believed that the military use of nuclear energy entailed risks that were not compensated by the potential benefits of its utilization for peaceful purposes. Those who held this view even went so far as to say that nuclear energy should not be used at all, so as to exclude any conceivable danger. Thus, in a study of the possibilities of atomic development, two American engineers wrote, in April 1947:[1]

'Are the benefits of industrial atomic power worth the risk? We believe they are not. We believe that the problems of the international control of atomic energy can be reduced to manageable proportions only by an international agreement not to develop industrial atomic power for a generation. We believe that most of the foreseeable benefits of atomic power to our generation *can be had without its use for industrial power plants*.*

'We propose the following compromise between the Russian and American positions. Let there be a world agreement that

[1] Daniel and Squires, *Bulletin of Atomic Scientists*, April-May 1947, p. 111.
* Our italics.

*no new industrial atomic plant shall be built** anywhere in the world for a number of years.'

Professor David F. Cavers of Harvard University expressed the view that the use of atomic energy should be banned 'until relations of greater trust and amity have been established among the nations.'[1]

This attitude, which reflects a mixture of optimism and pessimism, is referred to in the McKinney report (January 1956):[2] 'To some, atomic power seems to promise to remove all limits to our ability to produce and consume. To others, it raises the fear of obsolescence of capital investment and disruption of employment.'

The report comfortingly remarks that 'there are no facts to support either of these extreme views', and that 'much must still be done before atomic power becomes widely commercially competitive'. For good measure the report adds: 'Even then, atomic power plants will have to be constructed in substantial numbers before they will have any significant influence on the American economy.'

¶ *Slowness in developing the industrial use of the atom*

This phobia about a too rapid introduction of a new source of energy into the industry of a country in which the conventional sources of energy are still abundant explains to a large extent the initial slowness in developing the industrial use of atomic energy in the United States. It is, in fact, strange to note that, whereas an output of 100 kwh of useful energy was achieved with an experimental reactor in December 1951, it was not until 9 March 1953 that the American Atomic Energy Commission announced that the Oak Ridge laboratory had produced the small quantity of 150 kilowatts of electricity by means of nuclear fission. Up to the end of 1953 no systematic effort was made in the United States towards the industrial exploitation of nuclear power. Writing at about that time, Gordon Dean said:[3]

* Our italics
[1] *Bulletin of Atomic Scientists*, October 1947, p. 287.
[2] McKinney report, p. 30.
[3] *Report on the Atom*, p. 145.

'And now, except for the bomb-material reactors at the Savannah River plant, the Commission's reactor development program is mainly pointed in the direction of developing reactors to produce power for a practical military purpose: propulsion of submarines, aircraft and ships.'

It was only in the course of the year 1954 that the United States announced a programme for the production of electricity by means of nuclear fission.

2. THE 'PRODUCTIVE BOMB'

The fact that the world is divided into two socially and politically antagonistic blocs makes it impossible to bar the utilization of this new source of energy. As long ago as 6 September 1952 we published in *Le Monde* (Paris) an article[1] in which we discussed the probable repercussions of atomic energy. In that article we wrote:

'The capitalist state could not delay the utilization of atomic energy for productive purposes, particularly if another state—the communist state, for example—succeeded in using it. If the Soviet Union were able to make use of atomic energy for the expansion of production, it would be able to compete effectively with other countries whose production is based on the system of private enterprise. In that event, all countries—and in the first place the United States of America—would also be compelled to make use of atomic energy for the production of goods.'

In a second article, published in the same journal a year later, we stressed the fact that the industrial use of atomic energy would mean that the countries concerned would cease to concentrate all their efforts on the atomic armaments race, and we drew the following conclusion:[2]

'Having experienced the anguish of the race from the atom bomb to the hydrogen bomb, and living today in an atmosphere of uncertainty, humanity is anxiously awaiting the announcement of what we might call 'the productive bomb', that is to say, the freeing of this gigantic new force to promote the prosperity of the whole world. This is an objective worthy of every effort and every sacrifice.'

[1] Under the title 'L'énergie atomique menace-t-elle le système capitaliste?' This theme was further developed in our book *Planisme et progrès social*, p. 32 et seq. (Librairie Générale de Droit et de Jurisprudence, Paris, 1953.)

[2] This article appeared in *Le Monde* of 4 December 1953, under the title 'Qui aura le premier "la bombe productive"?'

We had not long to wait before this 'productive bomb' exploded. Six months later, the Soviet Union announced the putting into operation, on 27 June 1954, of the first nuclear power station. This station had an output capacity of 5,000 kilowatts, but the Soviet communiqué added: 'Soviet scientists and engineers are preparing the plans for other nuclear power stations which will have a capacity of from 50,000 to 100,000 kilowatts.'

¶ *An event of capital importance*

After having produced atom bombs and thermonuclear bombs the Soviet Union was thus the first country to succeed in harnessing nuclear energy for industrial use. It must be recognized that this fact represents a decisive step towards the peaceful utilization of the atom and an equally decisive factor in international atomic policy since 1954.

Mr. Sterling Cole, President of the American Atomic Energy Commission, while stating that he had not been at all surprised to learn that the Soviet Union possessed a nuclear power station, added that this news showed that the United States must pass legislation which would make it possible for private industrial enterprises to take advantage of the new advance in scientific knowledge.

The opening of the Soviet Union's first nuclear power station—which marked the end of the Western monopoly of nuclear 'know-how'—gave, as we have said above, a new turn to American atomic policy, and subsequently to international policy. Since that moment all countries have been striving to ensure that they shall not be left behind in the industrial exploitation of nuclear energy. Competition in the peaceful utilization of the atom has begun, with Great Britain for the time being in the lead. That country possesses at Calder Hall the world's first nuclear power station to produce electricity on an industrial scale. This station has a capacity of 90,000 kilowatts,

and among others now under construction there is one which will be the largest in the world, with a capacity of no less than 360,000 kilowatts.

3. WHICH COUNTRY WILL BE THE FIRST TO HAVE A THERMONUCLEAR POWER STATION IN OPERATION?

It was the antagonism between the two blocs which precipitated the entry of nuclear fission into industrial life. It is the same antagonism that will rapidly lead to the harnessing of thermonuclear energy. It is on the competition in this sphere that the peoples are founding their hopes, for they see—perhaps with an excess of optimism—the solution of all their difficulties in the exploitation of this immeasurable new source of energy.

The controlling of fusion for productive purposes appears likely to encounter certain obstacles, for the probable repercussions of the utilization of this new form of energy are arousing serious apprehension in the capitalist countries. Although, because of its relatively high cost, nuclear fission may not for the time being threaten the reign of the traditional sources of energy, the same will not be the case with energy produced by thermonuclear *fusion*, for here the generating cost will be so low that the repercussions are likely to be very considerable, if not indeed violent.

Later on we shall discuss why, in our opinion, atomic energy should not be entrusted to private enterprise. But we can at once affirm that the first victims of the harnessing of hydrogen will be precisely those enterprises whose activities are, directly or indirectly, linked with nuclear fission. If, as is to be expected, fission is ultimately superseded by fusion as a source of industrial energy, or if a way is found of converting the energy of radiation directly into electric power, the installations that have been provided for the extraction of uranium and thorium, as well as the nuclear fission power stations themselves, will become valueless.

¶ *Well-founded anxieties*

This explains the attitude adopted at the Geneva atomic conference by the representatives of certain countries on the

question of the possibility of the rapid harnessing of thermonuclear fusion. Referring to Dr. Bhabha's prediction that a method will be found for liberating fusion energy in a controlled manner within the next two decades, Admiral Lewis L. Strauss, head of the American delegation, said that fusion was 'a long-range project'—that it was 'a matter for the future'.[1] Although, as we have seen, the McKinney panel was optimistic as to the possibility of harnessing thermonuclear fusion, it none the less remarked:

'Even after the development of an operating prototype of a full-scale thermonuclear machine, many more years of intensive effort would very likely be required to develop an economically competitive source of thermonuclear power.'

It would thus seem a safe assumption that, if the United States had already succeeded in achieving controlled fusion—which is by no means impossible—it would not be disposed to announce this prematurely, and still less to hasten to exploit this achievement, for fear the psychological repercussions might have disastrous economic consequences.

Although the capitalist countries might not appear to have any great incentive to speed up their efforts to harness thermonuclear fusion for the production of usable power—an attitude which we believe would be a great mistake—this is certainly far from being the case with the communist countries. If, as we shall see in a later chapter, all social phenomena are, according to Marxist theory, conditioned by changes in the technique of production, and if this particular new technique can be expected to revolutionize the present economic and social structure, is it not likely that the communist countries are making intensive efforts to bring this new factor into play as quickly as possible? At Geneva, Professor Skobeltzin, head of the Soviet delegation, confirmed at his press conference on 20 August 1955 that fusion research was being carried on in the Soviet Union. We have also seen that during his visit to Harwell in October 1955 the Soviet scientist, Igor Kurchatov, indicated that great progress had been made by Soviet research workers

[1] Press conference at Geneva, 11 August 1955 (Report No. 14 of the Information Service of the American delegation).

in this sphere; and we have mentioned an article in *Etudes Soviétiques* of November 1956 which told of the development of a process that held out the promise of success in the control of this gigantic new source of energy. It seems by no means impossible, therefore, that the Soviet Union may be the first country to produce power by means of thermonuclear fusion, just as it was the first to operate a power plant working on nuclear fission.

However this may be, controlled thermonuclear fusion will before long have been achieved, and nothing will be able to delay its exploitation for industrial purposes. The world's ideological discord imparts a powerful stimulus to the efforts to master this new force, the potentialities of which are infinite.

¶ *The development of underdeveloped countries an acceleration factor*

Quite apart from ideological antagonisms, however, there is another factor whose role in the utilization of this new source of energy is particularly important. We refer to the underdeveloped countries. Handicapped by great distances, the inadequacy of their communication systems and the non-exploitation of their potential energy resources, these countries—more so than any industrialized country—are naturally intensely interested in this new energy source, which can be the means of freeing them from their present economic inferiority. China, India, Africa and Latin America undoubtedly have much more urgent need of new sources of energy than have the United States, Great Britain, or even Europe. If the peoples of the underdeveloped regions, who constitute *two-thirds* of the total population of the globe, and who at present suffer largely from chronic undernourishment, see that the key to their demographic problems is within their reach, their demand to have the benefits of the utilization of nuclear power will be so insistent that no one will be able to delay the peaceful exploitation of this new force, or will dare to contemplate its use for the purposes of war.

The inhabitants of these countries are intent on economic progress, and any methods whereby they might be enabled to

increase production and provide fuller satisfaction for their material needs are of vital concern to them. They realize that in order to arrive quickly at the desired result, it is essential that the whole of their national efforts in the economic sphere should be rationally co-ordinated. For this reason many of them have drawn up *long-term plans* designed to quicken the pace of economic development. For the successful execution of these plans an adequate supply of energy is indispensable. During a study tour made by the writer in China and India in September and October 1956, he gave several lectures on the role of atomic energy in the underdeveloped countries, and was much impressed by the eagerness shown by his audience to learn how soon atomic energy would become available for use on a large scale.

4. THE NECESSITY FOR MODIFYING OUR WAYS OF THINKING

It is from the double aspect of the ideological division of the world and the urgency of the energy requirements of the underdeveloped countries that the problem of the peaceful utilization of the atom must be regarded. These are two factors which, on the one hand, will expedite recourse to new sources of energy and, on the other, will determine the scope and intensity of the repercussions of their utilization. It would be a serious mistake to underestimate the importance of these factors, and to try to explain present economic and social phenomena in terms of the theories of the past.

We must realize that we have entered a new age, and that the new conditions demand a new 'world-outlook'. The difference between the iron age and the atomic age are so great that today's problems must be approached from a new angle. If we are to obtain the benefits that nuclear power can bring us, there must be a radical change in our manner of thinking. Albert Einstein, whose theory opened the door to the atomic age, laid great emphasis on this necessity in 'A Message to Intellectuals', issued to the press on 29 August 1948:

'Our situation is not comparable to anything in the past. It is impossible, therefore, to apply methods and measures

which at an earlier age might have been sufficient. We must *revolutionize our thinking*, revolutionize our actions, and must have the courage to revolutionize relations among the nations of the world. Clichés of yesterday will no longer do today.'

This new attitude of mind is essential, not only to dispel the menace of a malevolent use of the atom but also to achieve the most effective results from its peaceful utilization. For the scope and effects of the peaceful use of the atom will largely depend on the attitude of the peoples of the world and, above all, on the attitude of the large powers which stand at the head of the two blocs. International co-operation in the domain of nuclear policy, and international collaboration in the relative fields of research, will accelerate scientific progress, and make it possible to learn still more of nature's secrets and to place the new knowledge at the disposal of the whole world. Collaboration among scientists of all countries will hasten the harnessing of hydrogen—a revolutionary scientific advance, the effects of which will be of incalculable importance.

While nuclear fission offers great prospects of an abundant supply of energy, it is on the other hand attended by certain disadvantages, such as the complexity of the process for obtaining fissile material and the danger from radiation. For the time being these disadvantages limit the economic scope of this new source of energy. Even though there seems every likelihood that these obstacles will eventually be overcome, it must be borne in mind that the quantity of energy released by nuclear fission cannot be compared with that which could be obtained by means of controlled thermonuclear fusion. It is in fact to be anticipated that by furnishing an enormous amount of energy at negligible cost, hydrogen will make it possible to solve all man's material problems. Addressing a conference attended by over 400 British and United States scientists, at Berkeley, California, in February 1957, Sir George Thomson, British 1937 Nobel Prize winner for physics, said: 'The exciting and dramatic thing about this hydrogen project is that if it can be done there will be no limit to the energy that can be produced—far more than you would ever want.' An earlier statement

made by a Soviet scientist, Professor A. Kitaigorodski, should also be noted:[1]

'If a way is found of achieving controlled thermonuclear reaction . . . it will be possible to envisage a transformation of the surface of the globe and a modification of climate. The tremendous amount of energy that can be obtained from a very small quantity of nuclear fuel might make it feasible to establish a ring of nuclear reactors in, for example, the regions of perpetual ice, producing every day a quantity of heat comparable with that of the sun's rays. The practically inexhaustible resources of nuclear energy will make it possible for man to melt the ice of the polar seas and to irrigate deserts.'

This optimism is also reflected in the report of the American 'Panel on the Impact of the Peaceful Uses of Atomic Energy', which says that 'the concept of power resulting from controlled thermonuclear reaction has stimulated widespread enthusiasm because it could conceivably provide an unlimited energy resource beneficial to all peoples'.[2]

However, as we have already pointed out, the question of *fusion* was not discussed at the Geneva atomic conference, and the representatives of the various countries carefully avoided disclosing the stage so far reached in their research. This fact shows the extent to which we persist in thinking and acting on the old, outdated lines. Instead of seeking the co-ordination of all efforts in this field and thus expediting the accomplishment of this new scientific revolution, each bloc is jealously guarding its most important secrets, reserving them for the moment when their exploitation appears likely to give it the maximum advantage in the competition that has already begun.

The repercussion of this competition will depend to a large extent on the form it assumes. It might well be more in the nature of 'noble emulation' than of hostile competition in the old sense; and in that case it might conduce to economic and social progress in both blocs and eventually serve to draw them closer together. If, on the other hand, it takes the form of bitter economic rivalry, its repercussions will be violent, and

[1] See his article, 'L'atome au service de l'homme', in *Les Temps Nouveaux*, 1954, No. 46, p. 16.

[2] McKinney report, p. 51.

calculated to engender conflicts which, even if at first of a local nature, might rapidly develop into a threat to humanity as a whole.

It is, therefore, on our ability and willingness to understand the significance of the atomic age, and to adapt our mode of thinking to the new realities, that the prosperity and peace of the world will depend.

Chapter 4

THE BASIC PRINCIPLES OF NUCLEAR PHYSICS

I. STRUCTURE OF THE ATOM: NUCLEAR FISSION

If the use of nuclear power on a commercial scale is to be an economic possibility, its cost must be competitive with that of power derived from the conventional sources—coal, oil and water. This is the crux of the atomic question.

Before, however, we can go on to consider the present cost-structure of nuclear power production, and the factors that may be expected to modify it in the future, we must endeavour —without pretending to any specialist knowledge—to give a simple outline of the basic principles of nuclear physics and a description of the process whereby electric power is produced from nuclear energy. In doing so we shall draw freely on the mass of documentation made available at the Geneva atomic conference.[1]

¶ *The components of the atomic nucleus*

The atom is the smallest known unit of matter. It is about

[1] The following is a short list of useful works on nuclear energy:
J. G. Feinberg: *The Atom Story*, London, 1952
W. Heisenberg: *La physique du noyau atomique*, Paris, 1954
Sir George Thomson: *The Atom* (4th Edn.), London, 1955
S. Glasstone: *Source Book on Atomic Energy*, London, 1954
J. Rotblat: *Atomic Energy, A Survey*, London, 1954.
Power from Nuclear Energy (Notes prepared by Science Club with the co-operation of the U.K. Atomic Energy Authority), London, 1955
Théo Kahan: *Physique nucléaire*, Paris, 1954
E. Rabinovitch: *Explaining the Atom*, London, 1955
R. S. Shankland: *Atomic and Nuclear Physics*, New York, 1955
E. W. Titterton: *Facing the Atomic Future*, London, 1956
G. Wendt: *Nuclear Energy and its Uses in Peace*, UNESCO, Paris, 1955
'A Programme of Nuclear Power', British White Paper, Cmd. 9389, 1955.

one thousand million times smaller than a coconut. Its size in relation to that of an apple is comparable to the size of an apple in relation to that of the earth. It has been said that the French franc coin made of aluminium contains more atoms than the total number of grains of wheat harvested since man first began to cultivate the soil!

Although the world of atoms still remains mysterious and complex, it is an orderly world. It has often been compared with the solar system, and, although the comparison is fanciful, it does give some conception of the relative vastness of the empty space within matter. In this comparison the nucleus—which is the core of the atom—represents the sun, and the electrons which revolve round the nucleus represent the planets. The nucleus occupies only a thousandth of a millionth of a millionth of the volume of the atom. To give an idea of the extent of the empty space within the atom, Professor Frédéric Joliot-Curie suggests the following comparison: 'Suppose the circumference of the atom to be represented by the circumference of the Place de la Concorde in Paris; the nucleus would then be the size of an orange pip lying at the middle of the Place.'[1]

Before the discovery of radium, the atom was believed to be indestructible and immutable. It was the discovery of radio-activity that made it possible to study the structure of the atom.

The nucleus is the core at the centre of the atom and contains almost all its 'matter'. This matter is so dense that a lump of it the size of a drop of water would weigh two million tons,[2] and an unimaginable concentration of energy is therefore needed to hold it firmly bound within the nucleus.

The nucleus is composed of protons and neutrons. The *proton*, which is nearly two thousand times heavier than the electron, is the smallest atomic particle carrying a positive electrical charge. The positive electrical charge of the proton is equal to the negative electrical charge of the electron, so that these two charges cancel out, leaving the atom electrically neutral. The

[1] 'Ce qu'il faut désormais savoir', in the French review, *Horizons*, April 1955, p. 8.

[2] Gerald Wendt: *Nuclear Energy and its Uses in Peace*, UNESCO, Paris, 1955, p. 13.

neutron is practically identical with the proton: it has the same weight, but it does not carry any electrical charge. It is the number of neutrons which determines the weight and stability of the atom and gives to each nucleus its distinct individuality. It has been said that the volume of the protons, neutrons and electrons in the atom bears something like the same relation to the volume of the whole atom as does the size of a pea to that of the Great Pyramid! This means that the atom consists for the most part of empty space.

The structure of the atom is being intensively studied but, although much has been discovered, much still remains mysterious. The recent discovery of the *meson*[1]—a particle intermediate in weight between the electron and the proton—opens up new vistas for nuclear science. One eminent physicist, Professor C. F. Powell, has said that an understanding of the properties and behaviour of mesons will be of primary importance and may, indeed, disclose the basic concept of nuclear physics.

Still more recently—in October 1955—a new atomic particle, the antiproton or negative proton, has been discovered. This discovery was made in the laboratories of the University of California at Berkeley, and was made possible by the use of the university's bevatron. In the opinion of Dr. Ernest Lawrence it constitutes one of the major triumphs of nuclear physics. Physicists consider that, while antiprotons may have no practical application for the time being, they open up new and immense perspectives in nuclear physics. In announcing the discovery the Atomic Energy Commission, Washington, said that it was a highly important event which might prove to be the beginning of a new era in nuclear research. There appear to be good reasons for believing that the discovery will be of particular significance in the domain of thermonuclear fusion.

Thus, protons and neutrons constitute the atomic nucleus, which is surrounded by electrons. The atom does not normally exist in isolation, but combines with other atoms to form *molecules*. For example, a combination of atoms of chlorine and sodium produces the molecule of sodium chloride (NaCl).

[1] 'Meson' is a Greek word meaning 'middle', 'medial' or 'intermediate'.

Molecules are the smallest portions into which a material substance (simple or compound) can be divided without losing its chemical identity. All the molecules of any chemical body are identical; they all have the same volume and weight. There are also certain molecules which exist in isolation. The atom, which is the ultimate particle of every chemical element, has a specific weight. The atoms of one and the same element are identical, all having the same weight and volume. The weight of the atom is the sum of the weights of the protons and neutrons in its nucleus (leaving out of account the negligible weight of the electrons).

The *atomic weight* of an element is thus determined by the number of protons and neutrons in the nucleus. The element which has the lowest known atomic weight is hydrogen. Its nucleus has a single proton and no neutron. The weight of an atom of hydrogen is regarded as the unit of atomic weight (1). The oxygen atom weighs 16 times as much as the hydrogen atom. The heaviest known chemical element is uranium.

¶ *Isotopes*

Isotopes are a relatively recent discovery, made in the course of research work begun in 1919 by Thomson, Soddy and Aston. The existence of isotopes was confirmed beyond question when, in 1932, Urey, Bringwedde and Murphy discovered heavy water and heavy hydrogen (deuterium). Isotopes are different forms of one and the same chemical element, the difference between them lying only in the number of their neutrons. The chemical element *uranium* has several forms, or isotopes, each of which has 92 protons, while the number of neutrons varies and may be 141, 143, 146 or 147. The different isotopes of uranium are designated by their respective atomic weights: U.233, U.235, U.238 and U.239. Although these four isotopes of uranium have different atomic weights, they have identical chemical properties.

Hydrogen also has its isotopes. They are heavy hydrogen (deuterium) and tritium. The deuterium nucleus comprises one proton and one neutron, and its atomic weight is thus 2 (as against atomic weight 1 for ordinary hydrogen, whose nucleus

consists solely of one proton). The nucleus of tritium has one proton and two neutrons, and its atomic weight is thus 3. Heavy water is a combination of deuterium and oxygen.

¶ *Nuclear fission*

The process whereby an atomic nucleus splits into two smaller atomic nuclei of approximately equal size is known as *nuclear fission*. This fission reaction is, however, an extremely rare phenomenon in nature. Only the nuclei of the heaviest atoms are fissile. The fission of these heavy nuclei can be brought about by bombarding them with 'slow' neutrons. When the nucleus of the uranium isotope U.235 is struck by a slow neutron, it splits into two fragments which fly apart at tremendous speed. In this fission neutrons are liberated; these in turn strike other nuclei which they encounter and split them into two fragments; more neutrons are liberated, which strike and split yet other nuclei, and so the process continues. What is known as a *chain reaction* has been set up in the U.235, and with every fission a small part of the atomic mass is instantaneously converted into a tremendous quantity of energy in the form of heat. Ordinary chemical reactions generate heat up to say a thousand degrees Centigrade: nuclear reactions produce temperatures not of thousands, but of millions of degrees.

In a report prepared by the Science Club with the co-operation of the United Kingdom Atomic Energy Authority, the process of nuclear fission in uranium 235 is represented diagrammatically as follows:

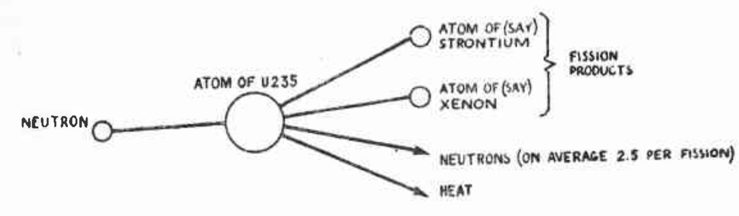


Fig. 1 The fission of an atom of Uranium 235

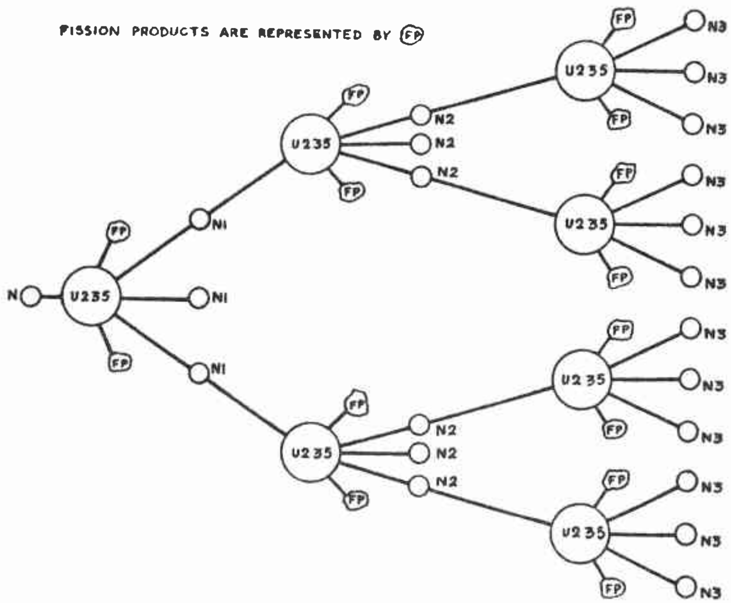


Fig. 2 A chain reaction with Uranium 235

If the chain reaction is not controlled, the result is a terrific explosion. In the atom bomb the explosion takes place within less than a millionth of a second of the commencement of the chain reaction. There can be no chain reaction unless the mass of fissile material, or nuclear 'fuel', is sufficiently large, the minimum amount required being known as the *critical mass* (or critical size). As it is impossible to 'control' the chain reaction in the atom bomb, it is essential that the fissile material employed should not form a critical mass until the exact moment at which it is desired that the chain reaction shall start, i.e., the moment at which the bomb is to explode. The fissile material contained in the bomb is therefore kept in segregated portions until that moment arrives. These portions are then hurled together by means of a detonator mechanism; the critical mass is thus attained, or exceeded, and the bomb instantaneously explodes. The critical mass required for the explosion of an atom bomb is

regarded as 'military information' and has not been divulged, but an O.E.E.C. report states that it is 'commonly said to be between 10 and 100 kg.[1] If the quantity is less than the critical mass, there can be no explosion.

2. NUCLEAR REACTORS AND FISSILE MATERIALS

Where it is desired to release nuclear energy for peaceful purposes, the chain reaction must be *controlled and continuous*, and for this to be possible the critical mass of fissile material must be present and the number of neutrons released must be at least *one more* than the number lost. The critical mass varies according to the type of reactor used: from 3 to 4 kg. of highly enriched nuclear fuel in the case of certain research-type reactors, to hundreds of tons of natural uranium in the large reactors installed at Calder Hall and elsewhere.

The production of nuclear energy by a controlled and continuous chain reaction is effected in a *reactor*. This is an apparatus in which 'atomic combustion' takes place, and for this reason is sometimes known as an 'atomic furnace'. It is also called a 'pile', because the earlier reactors were in fact piles of graphite and uranium. Numerous research reactors are being used by scientists in studying the structure of the atom and matter. Reactors are also being used to render chemical elements radioactive.

At the Geneva atomic conference several sessions were devoted to description and discussion of the various types of reactors then already in use or under construction. A report prepared by UNESCO for the conference enumerated the types of reactors constructed up to that date, and gave a conspectus of all data so far available on this subject.

All reactors work on the same basic principles, and all possess the following common features:

The uranium rods contain the fuel, that is to say the fissile material. Fission takes place in these rods by a chain reaction. When the fissile material in the rods has been consumed, they are replaced by new rods. The number of rods varies. In the

[1] O.E.E.C. *Possibilities of Action in the Field of Nuclear Energy*, 1956, p. 13. See also Kaempfert: *The Many Uses of the Atom*, New York, 1956, p. 16.

reactor installed in the first Soviet nuclear power station the number is 128. At the Calder Hall station it is more than 10,000.

The moderator is the material used in the reactor to slow down the neutrons. Graphite is the material generally employed, as it is readily procurable and relatively cheap. Graphite is used at Calder Hall, at Marcoule in France and at Kaluga in the Soviet Union. The moderating material used in other reactors is water or heavy water. In the 'heterogeneous' reactors the moderator (solid or liquid) is separate from the fuel, whereas in the 'homogeneous' reactors it is mixed with the fuel. The American Atomic Energy Commission, in its programme published in December 1956, recommends private enterprises to construct reactors using natural uranium as fuel and heavy water as moderator.

The control rods are made of neutron-absorbent metal, such as cadmium or boron. Their purpose is to maintain the chain reaction at the desired intensity by regulating the flow of free neutrons (the so-called 'neutron-flux'). The rods can be inserted into and withdrawn from the reactor core at will. If fully inserted they absorb all the neutrons and stop all fission reaction. As they are gradually withdrawn the reaction starts up, and the speed of the reaction and, consequently, of the release of energy, can be stepped up or down by adjusting the position of the rods.

The coolant is a means of preventing the reactor from becoming excessively hot; it performs the additional function of conveying heat from the interior of the reactor to the generator plant which converts it into electricity. Among the coolants that may be used are atmospheric air (as in the first reactor built at Marcoule), carbon dioxide (as at Calder Hall), or water under pressure. Ordinary water is used in the Soviet Union's first nuclear power plant, and its use is contemplated for the American reactor at Pittsburg. Finally, certain liquid metals, or an alloy of the two metals sodium and potassium, can be employed and are at present the subject of research in both the United States and Great Britain.

The shield surrounds the reactor on all sides to protect personnel from the dangerous radiation emitted in the reaction

process. This protective casing is made of solid concrete some seven feet thick, lined by a neutron-absorbent layer of steel or lead.

Every reactor constructed for the production of electric power comprises on the one hand standard industrial equipment, such as steam turbines, electric motors and compressors, and, on the other hand, specialized equipment such as monitors for checking radiation levels and electric devices for reactor control, etc.

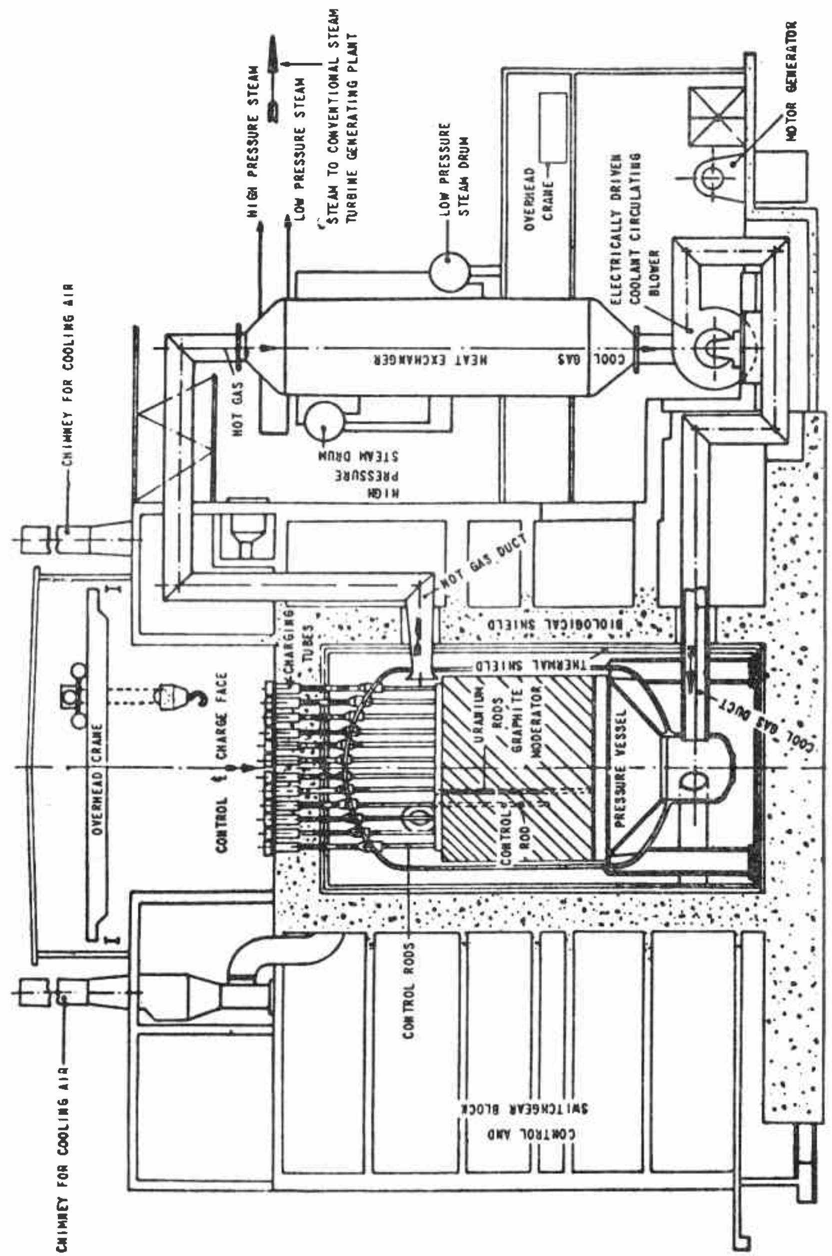
¶ *In search of the best reactor*

These main features of the present reactors will undoubtedly undergo considerable modification in the coming years. In a number of countries research is actively proceeding with a view to determining what type of reactor is the most appropriate for a given purpose. Speaking on 11 September 1956, Admiral Lewis Strauss, President of the American Atomic Energy Commission, said that the American plan was not to build an arbitrary number of nuclear power stations, each with its specified capacity in kilowatts; the Commission believed that what was proposed was more prudent and constructive, namely to go on developing nuclear reactor technology until such time as it became possible to compete economically with the kilowatts produced by the conventional methods.

¶ *Types of nuclear reactors*

We will now mention some of the basic considerations governing the design of nuclear reactors for the production of industrial power, that is to say, of electricity.

It might be said that the principle of the thermal power station of conventional type is not greatly different from that of the nuclear power station. In an ordinary thermal power station coal or oil is burned to produce steam which actuates the electric generators. In the case of the nuclear power station the boiler is replaced by the reactor, in which the fission takes place which releases energy in the form of heat. From this stage onwards the process is on the same lines as in a conventional power station.



A gas-cooled Power Reactor

Nuclear reactors may be classified as follows:

1. according to the purpose of the reactor: simple reactors which produce heat, and breeder reactors which produce not only heat but also new 'fertile' material;
2. according to the nature of the fuel: natural uranium, or uranium 'enriched' to a greater or less degree in fissile material (plutonium or uranium 233);
3. according to the type of moderator (graphite, heavy water, etc.);
4. according to the type of coolant (gas, water under pressure, a molten metal, etc.)

¶ *Characteristics of the Calder Hall Nuclear Power Station*

A number of reactors are in operation or under construction in various countries. Mention may be made, for example, of the reactor at Kjeller in Norway, in operation since 1951; the 'Borax I', built in 1953 at the Argonne National Laboratory in the United States; the 'Materials Testing Reactor', which has been in use since 1952 at the Arco testing station in the United States; the reactors (G.1, G.2 and G.3) at Marcoule in France; and the reactor at Kaluga in the Soviet Union. We are not qualified to enter upon a detailed examination of the problems of reactor technology, but we think it may be useful to mention the main characteristics of the Calder Hall nuclear power station which was put into operation on 17 October 1956 and is, for the time being, the largest nuclear power station in the world. The following interim data are quoted from *Nuclear Engineering* (special Calder Hall number, October 1956):

TYPE	Thermal heterogeneous.
PURPOSE	Plutonium production. Power production. Prototype for central power stations.
CAPACITY	42 MW from two turbines fed by four heat exchangers. Heat rating: 180 MW. Complete station includes four reactors. Maximum electrical output: 184 MW. Feed-back: 20%.

FUEL	Natural uranium. U as cast bars, 1.15 in. dia., 40 in. long. Elements in vertical channels, six per channel. Total number of channels: 1,696. Charge for criticality: over 20 tons. Total investment: 63 tons.
CANNING	Magnesium alloy—Magnox. Wall thickness of core: 0.072 in. Extended surface: single-start helical fin, 0.125 in. pitch, 0.43 in. radial width, overall dia. 2.125 in. Manufacture: cans turned from solid, swaged on to U. He filled.
MODERATOR	Graphite. Built up from 8 in. sq. interlocking blocks and tiles. Drilled 4-in. (av.) holes for fuel channels. Overall size, including reflector 36 ft. dia., 27 ft. high. Supported by ball bearings on 4-in. plates resting on diagrid. Total weight: 1,150 tons.
CORE	Size: 31 ft. dia., 21 ft. high. Lattice: regular square, 8-in. pitch.
COOLANT	Carbon dioxide at 100 p.s.i. circulated upwards through reactor. Flow: 7.1 million tons/hour. Ducting: 4 ft. 6 in. dia. Inlet temperature: 140° C. Outlet temperature: 336° C. Shielding cooling: blown air.
PUMPING	Four centrifugal blowers, one in each heat exchanger circuit. Total power absorbed: 5.44 MW. Speed Control: Ward-Leonard type, range 10/1.
CONTROL	Coarse: up to 60 rods ganged together. Fine: up to four manually operated. Normal operation: total of 40 rods. Rod construction: boron steel in stainless steel tubes. Suspension: stainless steel cable. Travel: 21 ft. Maximum rod speed for shut-off: 4 ft./sec. Minimum automatic rod speed: 0.5 in./min.
SHIELDING	6-in. thick steel plates. Concrete, on sides: 7 ft., on top: 8 ft. Minimum density: 150 lb./ft.^{3}, mean: 160 lb./ft.^{3}. Overall: octagon 60 ft. across flats. 90 ft. high. Total weight on foundations: 33,000 tons.

The thermal efficiency of the Calder Hall station does not exceed 21 per cent. The reactors are of the thermal heterogeneous type, being designed for the production of both power and plutonium. The heat produced by the fission reaction in natural uranium is used to turn water into steam in the heat exchangers, of which there are four to each reactor, and the steam is fed from the heat exchangers to turbo-alternators which generate electricity.

¶ *Nuclear fuel*

Whereas in the case of chemical combustion the fuel may be any one of a great variety of substances, this is not so in the case of nuclear fission. The 'nuclear fuels' which can be used as a source of energy in a reactor are limited to two quite different types: *fissile* materials and *fertile* materials.

The fissile materials, which are the fuel actually used in the reactor, are only three in number, and of these only one, uranium 235, exists in the natural state. It is one of the constituents of natural uranium, of which it forms 1/140th part. The two other fissile materials, plutonium and uranium 233, do not exist in the natural state, but can be produced by a process of transformation in a reactor.

The fertile materials are incapable of emitting nuclear energy directly, but they gradually undergo a partial transformation into fissile materials if placed in a working reactor. There are only two known fertile substances, uranium 238 and thorium 232. These can be transformed in a reactor into plutonium and uranium 233 respectively, both of which are fissile materials.

¶ *Cycle of fissile materials*

There are thus two 'raw materials' which are 'nuclear fuels': natural uranium and thorium. From these two raw materials the fissile elements uranium 235, plutonium and uranium 233 are derived, though this is a long and very expensive process. Gordon Dean estimates that more than three-quarters of the vast amount expended on the American Atomic Energy Programme went 'to build up the plants and laboratories that

uranium must pass through along the way to a bomb.[1] To give some idea of the cost involved in the separation of the fissile part of uranium, it is only necessary to mention that the cost of natural uranium is about $40 a kilogram, while a kilogram of fissile uranium 235 costs at least $25,000.[2]

Let us look at the different phases of the process of turning the raw material into fissile material in the nuclear industry.[3]

The first stage is the prospecting for natural uranium or thorium, carried out with the aid of special detectors (e.g. the Geiger-Muller counter). Then comes the extraction process. Apart from a few cases in which the ores are particularly rich, having a uranium content of over 1 per cent, the uranium content may be only a few kilograms—or even a few grams—per ton of ore.

Excluding the countries of the east, the four main producers of uranium are at present Canada, the Belgian Congo, the United States and the Union of South Africa.[4] As regards thorium, the largest producers are India and Brazil.

After extraction the ore is concentrated, either physically or chemically, and transported to a chemical works where it is transformed into an oxide or into chemical compounds.

¶ *Natural uranium and uranium* 235

The chemical compounds of natural uranium can be used as follows:

1. They can be transformed into metallic natural uranium, which is employed as a 'fuel element' in 'natural uranium reactors'. Here it should be noted that natural uranium

[1] Gordon Dean: *Report on the Atom*, p. 46.

[2] According to figures presented at the Geneva atomic conference by the U.S. Atomic Energy Commission. The Commission has prescribed for the future a flat price of $8 per pound of uranium concentrate, to take effect in 1962 (*U.S. News & World Report*, 28 December 1956).

[3] See particularly the O.E.E.C. report: *Possibilities of Action in the Field of Nuclear Energy*, January 1956, from which we have derived the data we give here.

[4] According to official figures, published by the *U.S. News & World Report*, 28 December 1956, the production of natural uranium concentrate in the United States in 1956 amounted to 16 million pounds, and it is anticipated that by 1959 production will reach 23.2 million pounds. The reserves of uranium are estimated at 300 million pounds, In the case of Canada, present annual production is 6.6 million pounds, and estimated production in 1959 28 million pounds; the reserves are put at 474 million pounds, and their value at 5,000 million dollars.

consists of 99.3 per cent of uranium 238 and 0.7 per cent of uranium 235.

2. Natural uranium is poor in fissile material; it can be 'enriched' in uranium 235 in installations known as isotope separation plants, which are very costly to construct and to operate.[1] The degree of enrichment can be varied according to requirements: the process can be continued until almost pure uranium 235 is obtained.

Thus, all enriched uranium is a mixture of natural uranium and of pure uranium 235. Its cost depends on the degree of enrichment, which may be as low as 10 per cent or as high as 90 per cent.

¶ *Thorium into uranium* 233; *uranium* 238 *into plutonium*

The chemical compounds of natural thorium, which are 'fertile material' and are four times as abundant as those of uranium, cannot be used directly for the production of nuclear energy, as can be done with natural uranium. It is necessary to transform them in a nuclear reactor into uranium 233. For this purpose 'converter reactors' are used, the fuel in which is a mixture of fissile elements and fertile elements. The proportion of fissile elements is often not more than 1 to 2 per cent. When thorium is bombarded by neutrons, radioactive thorium 233 is produced, and this is then transformed into fissile uranium 233. The same process is used to obtain plutonium; in this case the 'fertile' substance uranium 238 is transformed in a converter reactor into the 'fissile' substance plutonium. Plutonium is thus the product of a 'transmutation' of natural uranium.

Some converter reactors can produce more fissile material than they consume. They are known as breeder reactors, and we refer to them again below.

The chart on page 77, reproduced from the above-mentioned O.E.E.C. report, shows how it is possible for any country 'to

[1] According to the O.E.E.C. report already mentioned (p. 74) the cost of construction of an isotope separation plant for processing 1,000 tons of uranium per year (the depleted uranium residue having a concentration of 0.4% uranium 235) can be roughly estimated as varying from $85 million, where the concentration of enriched uranium 235 is 2%, to $300 million, where the concentration is 90%.

embark on an extremely varied nuclear programme by mixing fissile and fertile materials as desired'. The report adds that the chart indicates some, but not all the possibilities.

¶ *The breeder reactor and the self-reproduction of fissile material*

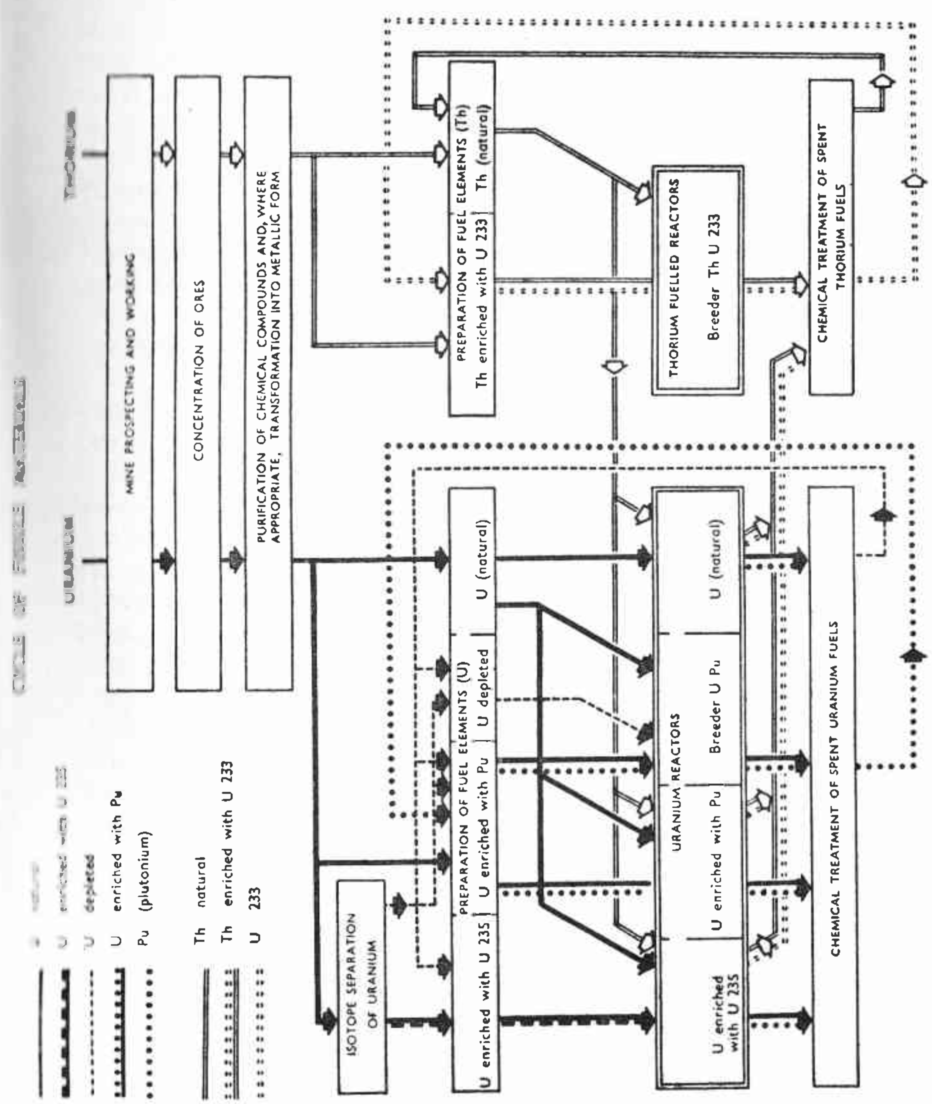
We have just mentioned the breeding reactor, which has the astounding property of producing more fissile material than it consumes. What is the nature of this 'breeding' process?

From the first years of the atomic age, nuclear scientists have been endeavouring to find a way of increasing the percentage of fissile material obtainable from natural uranium. They knew that it was theoretically possible to transform both natural uranium and thorium into fissile metal, not in the proportion of something like 1 per cent, but in a proportion equal to, or even *greater* than, the volume of the initial 'fuel' used. To this process of 'atomic self-reproduction' they gave the name 'breeding'. Dr Szilard informed the American Atomic Energy Commission in December 1954 that there were grounds for believing that the quantity of fissile materials would 'increase from year to year in geometrical progression'. Discussing the potentialities of the nuclear reactor of the future, Professor J. A. Wheeler predicted, in May 1946, that it would be possible, by burning a given quantity (say 1 kilogram) of new fissile material, to produce a greater quantity (say 1.1 kilograms) of new fissile material, such as plutonium. 'In this case', he said, 'we leave 1 kilogram of the new product in the plant to make up for the losses of the day and remove the other 0.1 kilogram to help start up a new pile.' He added that if such an advance could in fact be achieved, it would mean a great reduction in the quantity of fissile material that had to be produced from natural sources for the initial charging of nuclear reactors.[1]

In its report of 1948 the American Atomic Energy Commission described the 'engineering difficulties associated with breeding as enormous'.[2] The Commission nevertheless decided in 1951 to construct a special experimental reactor—the experimental breeder reactor subsequently used by the

[1] Quoted in S. H. Schurr and J. Marschak, *Economic Aspects of Atomic Power*, p. 8.

[2] Fourth Semiannual Report, Washington, 1948, p. 45.



Argonne National Laboratory in Idaho—in order to find out whether or not this breeding process was in fact a practical possibility. In June 1953, shortly before the expiry of his term of office as Chairman of the Commission, Mr. Gordon Dean made an important announcement which began with these words:[1]

'We have now reached still another milestone in the history of atomic energy development in this country. It is a development which holds out the promise of making a civilian atomic power industry even more *feasible and attractive*[2] in the long range than it has hitherto appeared to be.'

To bring out the full significance of this development Mr. Dean employed the following analogy:

'I would like to ask you to imagine a world in which only one hundred gallons of gasoline existed. When that gasoline was used up, gasoline would forever be gone from the earth. But let us imagine that we could make gasoline out of water by burning the gasoline we had in the presence of water. Let us say, for example, that by burning up our 100 gallons of gasoline we could change 90 gallons of water into new gasoline, and that thereafter we could, by burning gasoline in the presence of water, always make new gasoline equivalent to 90 per cent of that which we burned. By such a process we could quite obviously greatly stretch out our supply of gasoline, but we could hardly expect to stretch it out indefinitely, for we would always be making a little less gasoline than we consumed. Ultimately we would run out of gasoline before we ran out of water, and all the rest of the water in the world would be useless to us so far as gasoline production was concerned.

'But to pursue our oversimplified analogy still further, let us assume that we succeeded in developing a way by which we could produce 100 or more gallons of new gasoline from water for every 100 gallons we burned. Suddenly we would have made it possible for ourselves to change gradually all of the water in the world into gasoline. Our gasoline shortage would have vanished.'

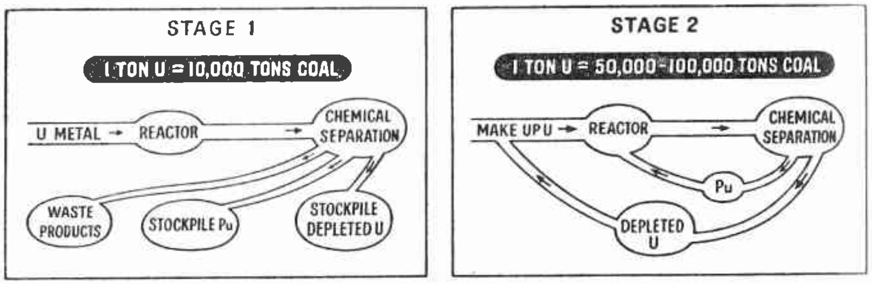
[1] *Report on the Atom*, pp. 161-2.
[2] Our italics.

By this announcement the Chairman of the American Atomic Energy Commission told the world that the possibility of 'breeding' fissile material had been proved experimentally in the Argonne laboratory. This new development will greatly accelerate the generalization of the use of nuclear power for industrial purposes for, once this process can be used on a large scale, the quantity of new fissile material to be obtained from natural sources will become extremely small. According to calculations made by Soviet nuclear experts, by increasing the number of its breeder reactors the U.S.S.R. alone could, within thirty years from now, satisfy the whole of humanity's nuclear fuel requirements.[1]

In a breeder reactor working on the uranium-plutonium cycle, not only is heat emitted which can be used to generate electricity, but more fissile material is produced than is consumed. By this process it will be possible greatly to raise the level of reactor efficiency. Taking part in the Panel Discussion on Atomic Energy, organized at Washington in September 1956 by the Bank for International Reconstruction and Development, Sir John Cockcroft referred to the success already achieved in Britain in the 'regeneration' of fissile material in experimental breeder reactors. It had been anticipated that in the early stations to be built under the British nuclear plan it would be possible to extract from each ton of uranium the heat equivalent of ten thousand tons of coal. Commenting on this estimate, Sir John said that in the first phase of the plan the plutonium produced in the breeder process, as well as the depleted uranium, might be stockpiled for a time, but that later on they expected to recycle all the plutonium, with the result shown in 'Stage 2' of the diagram on page 80.[2]

It will be seen from this diagram that when it eventually becomes possible to feed back into the reactor all the plutonium it has produced, it may be expected that one ton of uranium will yield the heat equivalent, not of 10,000, but of 50,000–100,000 tons of coal.

[1] According to an article in the Soviet journal *Komsomolskaya Pravda* of 4 September 1954.
[2] International Bank for Reconstruction and Development: Informal Panel Discussion on Atomic Energy in Economic Development, 27th September 1956.



FUEL CYCLES

In Great Britain experimentation is being carried out with various types of breeder reactor. In its report for the twelve months ended 31 March 1956, the U.K. Atomic Energy Authority stated that a fast breeder reactor (ZEPHYR) had been in operation throughout the period, and that the data so far available indicated that in ideal conditions a breeding ratio of about 2 had been obtained, that is to say, the reactor had produced about twice as much fuel as it consumed. A large-scale experimental fast reactor at present under construction at Dounreay in the north of Scotland will undoubtedly make an important contribution to the further progress of breeder research.

There can be no question that the 'breeder' is the reactor of the future and that its emergence from the experimental stage will mark an immense advance in the exploitation of nuclear energy, and will, as we shall see later, lead to an appreciable reduction in the cost of production of power from this source.

3. THERMONUCLEAR FUSION

A *thermonuclear* explosion is the direct opposite of an atomic explosion. It is a question not of nuclear 'fission' but of thermonuclear 'fusion'. In the case of fission the neutrons bombard and split *heavy atoms*, such as those of uranium 235 or plutonium 239, and cause their transformation into other, lighter atoms, with the release of a great amount of energy. In the case of fusion, the neutrons bombard *very light atoms*, such as those of hydrogen, helium or lithium, and these atoms do not split, as in the case of fission, but combine or 'fuse' together to produce heavier atoms.

Thermonuclear fusion can be effected between the different isotopes of hydrogen, with a resultant formation of helium. Deuterium and tritium are isotopes of hydrogen, the former existing in enormous quantity in sea-water. When the fusion of deuterium and tritium takes place in a thermonuclear reaction, a vast amount of energy is released. The light hydrogen atoms remain inert at ordinary temperatures, but explode when heated to a sufficiently high temperature. The temperature required for 'fusion' is enormously high—something of the order of that which exists at the centre of the sun. (Astronomers believe that solar heat is the result of a nuclear chain reaction). Professor O. R. Frisch calculates that for thermonuclear fusion a temperature of some millions of degrees must be attained before the energy produced equals the energy lost. Once that point is passed the rate of energy output becomes much greater than the rate of loss, and the fusion reaction takes place within an extremely short space of time, during which the greater part of the materials used fuse together and the temperature soars to a fantastic height—possibly as much as a thousand million degrees.[1] To produce the temperature required to initiate a thermonuclear reaction in a hydrogen bomb, an ordinary atom bomb has been used as a detonator.

Thermonuclear fusion causes a more complete disintegration of matter than does fission, and consequently releases a much greater quantity of energy. It is believed that, while fission destroys less than one-thousandth of the material employed, fusion destroys something like one-hundredth. Although the calculations vary, it seems to be generally accepted that the thermonuclear bombs so far made are from 1,000 to 2,500 times more powerful than the Hiroshima atom bomb.

The experimental explosion of a thermonuclear bomb in the Eniwetok archipelago in November 1952 completely wiped out the small island of Elugelab. The energy liberated by that explosion was estimated at 3 megatons. In further explosions in March/April 1954, still greater quantities of energy were released. It would seem that the hydrogen bomb explosion of

[1] 'Atomic Weapons', in *Atomic Energy*, a survey edited by J. Rotblat, London, 1954, p. 15.

1 March 1954 produced 14 megatons of energy and that of 26 March 1954 17 megatons, as against the 3 megatons anticipated by the physicists. The energy released in the thermonuclear bomb test carried out in the Soviet Union in November 1955 is also believed to have been equivalent to the explosive force of several million tons of T.N.T. (one estimate having indeed been as high as 50 million tons!). The Tass agency claimed on 26 November 1955 that the Soviet explosion had been the most powerful the world had yet known. It would seem that the Soviet test, like that which took place in the United States in March 1954, was not carried out with a simple hydrogen bomb, but with a hydrogen-uranium bomb. The reaction which results in the explosion of this type of bomb is three-phased: this time it is a question not of a fission bomb, or a fusion bomb, but of a 'fission-fusion-fission' bomb. The first phase of the process is the fission which takes place when the detonator—in the form of an atom bomb—is touched off to produce the temperature required for the thermonuclear reaction. In the fission reaction neutrons are emitted which transform into tritium the lithium which forms the charge of the thermonuclear bomb. The second phase is the fusion of the tritium with deuterium (heavy hydrogen), and the third is further fission—that of an envelope of uranium around the lithium.

¶ *The difficulties of achieving controlled thermonuclear reaction*

The great question today is: how soon will the nuclear scientists and technicians succeed in harnessing thermonuclear reaction for the production of useful power? In Chapter 3 we referred to various forecasts that have been made. Even the least optimistic of them does not put the period required at more than twenty years. We have already said that in our own view the progress recently made in this sphere suggests that the date is not far distant when economic power will be produced by means of controlled thermonuclear fusion.

What are the main obstacles to the achievement of controlled fusion?

The fission of a heavy nucleus is, as we have seen, the result

of the capture of a neutron by the uranium nucleus. As the neutron does not carry an electric charge and, consequently, is not repelled by the nucleus, the reaction takes place relatively easily.

In the case of fusion, on the other hand, the two light-element nuclei which come into contact both carry a positive charge, and each violently repels the other. To overcome this repulsion and bring about fusion requires more than a hundred million degrees of kinetic energy.

Thermonuclear reaction can therefore only take place at immensely high temperatures, and the thermonuclear material, which is known as 'plasma', cannot exist at such temperatures except 'in the form of a chaos of electrons and of atomic nuclei denuded of their envelope of electrons'.[1]

The attainment of the fantastic temperature necessary for the initiation of the thermonuclear reaction is the main problem with which the research scientists and technicians are at present grappling. 'It is clear', says the McKinney report, 'that no container made of ordinary material can confine the reaction zone at these temperatures.'

In a recent article the Soviet scientist, Igor Kurchatov, wrote: 'When deuterium is heated, its particles disperse in all directions and impart their energy to the walls of the container. . . . The loss of energy is so great that, in the absence of calorifugal insulation, it becomes a practical impossibility to go on raising the temperature.'

A recent development, however, makes it seem possible that a way may shortly be found of producing thermonuclear reaction of high intensity in the laboratory. According to a report in *Etudes Soviétiques* of November 1956, the Soviet physicists, A. Sakharov and I. Tamm, have succeeded, by using a magnetic field, in obtaining calorifugal insulation of the 'plasma', thus making it possible to maintain the particles in the plasma, while preventing them from imparting their heat to the container walls. In this way they were able to raise the temperature of the plasma to a million degrees.

[1] *Etudes Soviétiques*, November 1956.

Such a temperature had never previously been obtained in a laboratory. Can it be raised still further, to the level required for thermonuclear reaction? The scientists are guarded in their prognostications.

'Only continual research will enable us to say', writes Kurchatov in the above-mentioned article, 'whether we are getting nearer to the control of thermonuclear reactions of great intensity.'

So far, no information has been forthcoming as to what progress may have been made in American research in this domain, beyond an announcement in April 1956 that a first thermonuclear reaction had been obtained in a laboratory. Even this meagre disclosure, however, tells us that the Americans also are on the way to solving a problem which a short time since was regarded as insoluble.

This problem is also being intensively studied at the British nuclear research establishment at Harwell, and the progress achieved to date has been described in a number of technical reports published in a recent issue of the Proceedings of the British Physical Society.

4. RADIOISOTOPES

Before scientists succeeded in disintegrating the atom, radioactive elements were relatively rare, and very costly to produce. Radium was the only usable source of radiation, but at about $100 per milligram its cost was prohibitive. Radioisotopes had been produced before 1939 by means of cyclotrons, but only in very small quantities. They are now obtained as a by-product of nuclear fission, in very considerable quantities and at much lower cost. According to Gordon Dean, 'in a few weeks one nuclear reactor can produce, at a cost of about $10,000, as much radioactive carbon as one thousand cyclotrons could produce at a cost of more than $100,000,000'.[1] At the Geneva atomic conference great stress was laid on the importance of this discovery of a means of producing radioisotopes cheaply and on a large scale.

[1] *Report on the Atom*, p. 171.

Broadly speaking, there are two ways of producing radioisotopes:[1]

1. Atoms of the nuclear fuel in the core of a reactor are converted into radioisotopes as a result of the bombardment by neutrons to which they are subjected during the fission reaction. At present, however, the extraction and purification of these 'impure' radioisotopes is difficult and expensive.
2. The element of which a radioisotope is required is inserted into a reactor and exposed to neutron bombardment for the period necessary to convert it into the desired radioisotope.

In one or the other of these two ways, a great range of chemical elements can be rendered radioactive.

The utility of radioisotopes lies principally in the fact that, as they emit beta and gamma rays without losing their chemical properties, they facilitate the study of many chemical, physical and biological processes. Radioisotopes used for these purposes are known as tracer isotopes, or tracers, because they reveal their whereabouts by the rays they emit, and by means of a Geiger counter the research worker can follow their path through whatever body or substance he may be studying. This new technique enables specialists in many branches of science to observe phenomena that escape the unaided natural senses, and to study functions and reactions that have hitherto remained undiscovered or obscure.

¶ *Radioisotopes in the service of medicine*

Radioisotopes are rendering inestimable service in medicine, and specialists in that field rightly regard them as 'the most important discovery since the invention of the microscope'.

The most spectacular application of radioactivity to medical use is what has been called the 'cobalt bomb'—an extremely economical and effective substitute for X-rays and radium. It is calculated that one ounce of radio-cobalt, produced at a

[1] At Session 19-A of the Geneva Conference, Dr. A. F. Rupp, of the Oak Ridge National Laboratory, described in detail the processes employed for the production of radioisotopes.

cost of about $17,500, emits as much radiation as would $50 million worth of radium! Moreover, while radium is very scarce—it has been estimated that not more than 2½ kilograms have been produced since it was first discovered some fifty years ago—ordinary cobalt can be turned into radioactive cobalt in unlimited quantities. Non-radioactive cobalt fragments are exposed to radiation and converted into a powerful source of gamma rays. According to a report submitted by Dr. A. F. Rupp at the Geneva Conference, a few ounces of cobalt can be given a radioactive intensity equal to that possessed by several pounds of radium. The first cobalt bomb was made in Canada in 1952 and since then this device has been used to fight cancer and other diseases.[1] At the present time, radio-cobalt 60 and thulium are being used extensively in the United States, the Soviet Union and many other countries. A paper submitted at the conference by M. Brucer reported that radio-cobalt with a radioactive power equal to that of 2,400 grams of radium was being used in the United States for 'teletherapy' treatment of malignant tumours.[2] Mme. Kozlova reported that 160 medical institutions in the Soviet Union had almost simultaneously been supplied with sets of radioactive cobalt preparations and that in the case of, for example, eyelid skin tumour, recovery was obtained in 94 per cent of 450 cases treated.[3]

Radioisotopes are being used for the diagnosis and treatment of other diseases. Radioactive iodine, for example, is used in the investigation of thyroid disorders, radioactive phosphorus in locating cerebral tumours, and radioactive colloidal gold in neuro-surgery. Radioisotopes are also playing an important role in the fight against leprosy, poliomyelitis, malaria, pernicious anaemia and germ-carrying insects. Each year the United States, the United Kingdom, Canada and the Soviet Union supply considerable quantities of radioisotopes to other countries. It is said that consignments by the United States alone now number about 35,000 a year.

[1] The medical use of radioisotopes was the subject of several papers submitted at the Geneva Conference. Mention may be made in particular of those by M. S. Warren (United States) and M. A. Korsanov (U.S.S.R.).

[2] Document P/446.

[3] Document P/685.

¶ *Tracer isotopes in the service of biology*

Tracer isotopes are also an invaluable asset in biological research. With their aid the complete course of certain chemical elements through the human body can be followed. By injecting a radioisotope into a patient's bloodstream it is possible, for example, to locate the exact spots at which there are symptoms of the disease from which he is suffering. Thanks also to radioisotopes, it has been proved that the old theory of metabolism was erroneous. The body does not immediately eliminate nutritive substances which it cannot for the time being assimilate. Changes are constantly taking place in the tissues of the body: new cells are being incorporated in the organism, while old cells that have become useless are excreted. With the aid of radioactive calcium it has been possible to show that even the bones are similarly renewed and that, as a result of this constant process of replacement, the whole body is rebuilt every year. Biologists attach immense importance to this discovery, which throws an entirely new light on the fundamental life-processes. The tracer method is also being intensively used in the study of photosynthesis, the process by which green plants assimilate water and carbon dioxide from the air and, with the aid of sunlight, transform them into the various chemical compounds that are necessary to growth. Information communicated at the Geneva conference showed that, thanks to tracer isotopes, research-workers are gradually fathoming the secret of this highly complex physiological process.[1]

There can therefore be no doubt that the use of atomic energy in the medical domain must eventually bring about a prolongation of the average length of human life, and that for every nation this increased longevity will mean greater productive capacity, an expanding population and a growing proportion of older people. As the McKinney report remarks, it will no longer be necessary to look on people of 65 as having come to the end of their 'useful' life.

The contribution that atomic energy can make to the

[1] At the Session of 16 August 1955, devoted to the subject of radioactive isotopes in physiology and biochemistry, Dr. M. Calvin (United States) and Dr. A. M. Kouzin (Soviet Union) reported on the progress achieved in this domain.

betterment of human health will, however, depend on three pre-conditions:[1]

(a) the training of doctors, nurses and technicians in sufficient numbers;
(b) the provision of research centres or installations, with the necessary qualified staff;
(c) the rapid diffusion of the most up-to-date information about progress in medical science.

¶ *Radioisotopes in agriculture*

Notable results have already been achieved by the use of radioisotopes in agriculture and industry. Research carried out with the aid of tracer isotopes has enabled farmers to effect very considerable economies by the adoption of more rational methods. Radiophosphorus, for example, makes it possible to study the action of a phosphate fertilizer in the soil and in the plant, and to discover when and how the fertilizer should be applied so as to produce optimum results. One authority, quoted in a UNESCO publication,[2] has said: 'The advances made with isotopes in the knowledge of phosphate fertilizers during the past four years is equal to and may exceed the progress in this field during the preceding 50 years'. Experiments have shown that by introducing radioactive elements into plants, their yield can be appreciably increased (by the destruction of parasites, bacteria, etc.). Promising results have also been obtained in the use of radioisotopes for improving or preserving the quality of fruits and other foodstuffs (retention of freshness in storage, quickening or slowing up the ripening process, etc.).[3]

Radioisotopes can be used to cause or accelerate artificial mutations in plants, while at the same time they make it possible to study every phase of such mutations. Experiments

[1] The McKinney report emphasizes the importance of these pre-conditions and makes recommendations with regard to their fulfilment.
[2] 'The Promise of Atomic Power', *UNESCO Courier*, Special Number 12, 1954, p. 33.
[3] At the first European congress on the agricultural applications of nuclear energy (held at The Hague in November 1956) the delegates devoted particular attention to the subject of the preservation of foodstuffs.

have been reported in which barley has been given some of the qualities of wheat, and wheat some of those of barley. Changes in the quality and characteristics of maize have been brought about by exposing the plant to radioactivity. It has been found possible by the same means to grow cereals which have longer and sturdier stalks and are thus better adapted to mechanized cultivation. It begins to appear conceivable that by combining radiation with natural crossing, and by the judicious use of appropriate chemical fertilizers, the whole picture of the world's agriculture could little by little be transformed. At the Geneva conference Professor Gustafsson (Sweden) asserted that radioactivity would enable science to bring about within *two or three years* effects which natural evolution would take *thousands of centuries* to produce.[1]

There can be no doubt that radiation and tracer isotopes will make an increasingly valuable contribution to agriculture. In a report presented at the Geneva conference, the Food and Agriculture Organization (F.A.O.) expressed the opinion that the application of nuclear energy and its by-products to agriculture may prove of greater value in helping to provide for the needs of the expanding world population than as a source of industrial power alone.[2]

¶ *Radioisotopes in industry*

Radioisotopes are already rendering valuable service to industry in a great variety of ways. It is calculated that with one million dollars' worth of radioactive isotopes bought from the Atomic Energy Commission, American industry is enabled to effect in a single year operational economies to a total of about 100 million dollars. Some 1,200 American firms are regularly using isotopes in the study of manufacturing processes, as well as in pure research.

Radioisotopes provide industry with an inexpensive, simple and rapid means of checking finishing processes that were formerly difficult to control. They are being used to obtain increased speed and automation in a number of technological

[1] Session of 15 August 1955.
[2] Document P/780: 'The Uses of Atomic Energy in Food and Agriculture'.

processes and, in conjunction with modern electronic devices, for measurement, automatic control and remote control in a wide variety of production techniques. They can be used, *inter alia*:

(a) for measuring the thickness of material during manufacture, without the necessity for physical contact with the material;
(b) in selecting suitable ores for the production of cast metal, and suitable metals for new alloys;
(c) for measuring friction in machine parts and testing resistance to wear in automobile tyres, etc.;
(d) for checking the flow of a succession of different oils through a pipe-line.

Thus, in medicine, biology, agriculture and industry radioisotopes are rendering increasingly valuable services. The advantages offered by radioisotopes are already immediately accessible to any country which can construct or acquire nuclear reactors. As we have seen, results of fundamental importance may confidently be anticipated from the use of radioisotopes in the study of photosynthesis and of the functioning of organic and inorganic matter.

Chapter 5

PROGRAMMES FOR THE INDUSTRIAL USE OF ATOMIC POWER; THE COST OF ITS PRODUCTION

I. INDUSTRIAL APPLICATIONS OF ATOMIC POWER

The application of atomic power to industrial use is a new economic factor of the utmost importance. This is because, as we have seen, the conventional sources of energy are rapidly diminishing, and for the time being atomic energy appears to be the only alternative source capable of making good the growing deficiency.

Apart from the production of radioisotopes, which are already rendering inestimable service, there are three main uses for atomic energy:

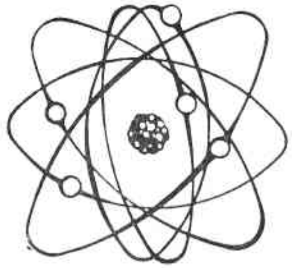
(a) the production of electricity;
(b) the propulsion of means of transport;
(c) the production of heat for industrial purposes and for space-heating.

Before turning to the question of the cost of producing atomic power it may be useful to outline briefly the present state of research in these three spheres.

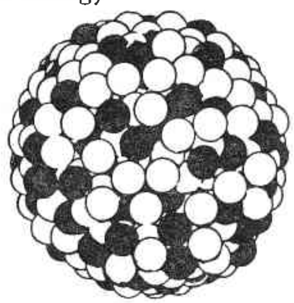
¶ *The production of electricity*

As regards the production of electricity by means of nuclear fission, the problem has already been solved from the technical point of view. As we have seen in Chapter 4, the heat emitted when nuclear fission takes place is used to run turbo-generators for the production of electricity.

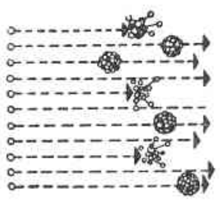
Electricity from Nuclear Energy



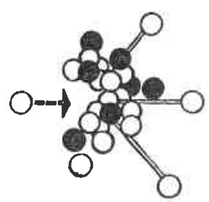
Atoms are like tiny solar systems. In the centre is the nucleus (or sun). Around it revolve electrons (the planets), each in its own orbit.



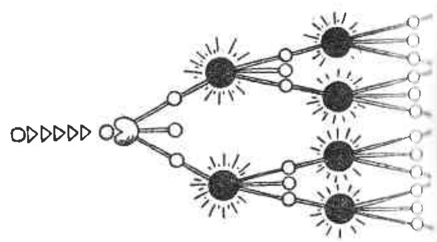
A nucleus is a cluster of closely packed particles of "protons" and "neutrons".



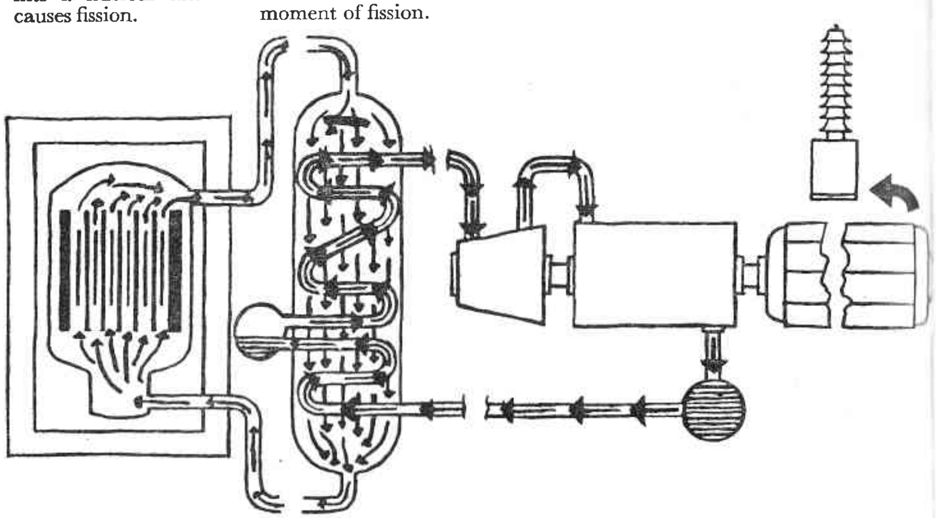
When atoms are machine-gunned with neutrons, occasionally a neutron hits a nucleus and causes fission.



Fission releases energy, mainly as heat. Commonly two or three free neutrons are shot off at the moment of fission.



Fission-released neutrons may strike other nuclei and cause fission: and so on in chain-reaction.



In a power station nuclear reactor chain-reaction is controlled to give the continuous heat release desired. Steam from the heat exchangers drives turbines which drive the electric generators in the usual way.

In the United Kingdom, the Soviet Union, the United States and France nuclear power stations are already in operation, producing electricity in ever growing quantity; and those countries are planning the construction of further stations with a high output capacity.

When we come to examine the question of the cost of nuclear power production we shall refer to the nuclear programmes which the larger countries have in contemplation for the coming years.

¶ *Atomic propulsion*

Nuclear power will be of immense significance in the sphere of transport, which in all countries now absorbs a high proportion of the available supply of conventional power. In the case of the United States it is calculated that motor vehicles, aircraft, ships and locomotives use about 25 per cent of the total power output. The proportion is roughly the same in other countries. What are the possibilities of using nuclear power for propulsion?

For the moment its use for that purpose is confined to the military sphere. An American submarine, the *Nautilus*, was put into commission on 10 January 1955. This vessel, which has a length of 90 metres, a displacement of 3,000 tons and a maximum speed of 25 knots submerged, cost $30 million. In January 1957 it was reported in the American press that the *Nautilus* was about to be refuelled for the first time.[1] In less than two years it had sailed more than 50,000 miles, much of the distance submerged, and its performance had included an unbroken cruise of 66 consecutive days. The construction of a second American submarine, the *Seawolf*, begun on 22 July 1955, has just been completed.

Now that the *Nautilus* has demonstrated the practicability of nuclear-powered marine engines, plans are being drawn up in a number of countries for the utilization of nuclear power for the propulsion not only of ships, but of various other forms of transport.

If the use of nuclear fission to power marine engines becomes generalized, this will mean a complete revolution in navigation,

[1] *New York Times* (International Edn.), 7 January 1957.

for ships will be able, on a very small quantity of nuclear fuel, to travel thousands of miles at more than present-day cruising speeds, without intermediate refuelling. In addition, this form of propulsion will undoubtedly be adopted for other forms of transport. The Soviet journal *Red Star* has described the potentialities of nuclear power in the domain of aviation and of transport in general as immense. Referring in particular to motor transport, this journal stated that an atomic engine was under development which would enable the Russian 'Pobyeda' car, which at present consumes 10 to 11 tons of petrol per 100,000 km., to cover the same distance on power generated from a mere 60 grams of uranium.

There are two factors which still impede the generalization of nuclear propulsion:

(a) the difficulty of providing protection against dangerous radioactivity;
(b) the high cost of the nuclear reactor.

The first of these two difficulties is particularly marked in the case of motor vehicles and aircraft, for the shielding required is much too bulky and heavy for these types of transport. In a ship there is plenty of room for the installation of effective shielding walls, and in fact, as we have seen, the practical possibility of nuclear ship propulsion has already been definitely established. A number of countries are already busy on plans for nuclear-powered warships, particularly submarines, and are also engaged in active research with a view to the application of nuclear propulsion to tankers and other commercial ships. The United States Navy is said to be planning or building seventeen nuclear-powered vessels in addition to the *Nautilus* and *Seawolf*, including an aircraft carrier and a missile cruiser.[1] The American Atomic Energy Commission has concluded a contract for the building of a nuclear-powered vessel for the transport of both passengers and cargo. This boat, which will cost $37 million, is expected to be ready by 1959; it will carry 100 passengers and 12,000 tons of cargo, and will have a speed of 21 knots.

The Soviet Union also undoubtedly has an atomic submarine

[1] *New York Times* (International Edn.), 7 January 1957.

programme, and is known to have begun work already on a nuclear-powered 16,000-ton icebreaker.

In Great Britain, according to a statement issued on 1 January 1957 by the British Shipbuilding Research Association, intensive work is being done on the development of reactors suitable for the nuclear propulsion of ships. The statement added that, although it was not possible to forecast when economic nuclear units for ships might be evolved, the possibilities were such that the studies and development work now in hand were worth pursuing actively. On 6 February 1957 *The Times* reported that an order had been placed for the construction of a prototype nuclear propulsion submarine. Sir John Cockcroft has said that a large gap in costs has to be bridged before nuclear propulsion becomes commercially attractive. The problem of protection against the radiation hazard would, he thought, probably have been solved within the time it would take to develop and prove the technical feasibility and economic advantage of the application of this system of propulsion to merchant ships.

¶ *Are nuclear-powered tankers already an economic proposition?*

Once the problem of safety is solved, there should be no further major obstacles to the commercial exploitation of nuclear propulsion. Consider the great advantages that this system of propulsion offers for merchant shipping. It will give higher speed, with a very small consumption of nuclear fuel; coal bunkers will be eliminated and more cargo space will thus be available; the duration of voyages will be shortened; and working expenses will be reduced because even the small volume of nuclear fuel will only require renewing at long intervals and the cost of operating the nuclear reactor will be very low.

These advantages will to a great extent offset the high initial cost of the reactor. (Each nuclear engine would at present cost about 10 million dollars.) This will be particularly true in the case of large vessels with high-powered engines, as for example tankers and boats carrying bulk cargoes of ore, which spend the greater part of their time at sea. For these vessels, the elimination of the deadweight of coal or oil fuel (which is often as much

as ten per cent of that of the cargo) will appreciably increase earning capacity. It has been calculated that in the case of a 20,000-ton tanker the increase might well amount to something like a million dollars a year.[1] The additional earnings would, of course, be considerably greater than this in the case of tankers in the 100,000-ton class. It might even be asserted that nuclear-powered tankers are already a commercial proposition, notwithstanding the great capital cost of a nuclear reactor. The American maritime administration estimates that a nuclear-powered tanker will cost 40 per cent more to build than one powered by the conventional type of marine engine. The American Atomic Energy Commission has already given instructions for the preparation of plans for a tanker of 35,000–40,000 tons displacement.

The McKinney report (published in January 1956) anticipated that nuclear energy could become an important source of power for the merchant navy in less than 10 or 15 years. It added: 'Atomic-powered replacements for all present United States ocean-going tankers exceeding 15,000 tons deadweight, in the period 1960–65 on, would result in construction of 300 or more such vessels over a period of 20 years.'

It looks, however, as though the change-over will be more rapid than this. According to an announcement made on 25 January 1957 (about one year after the publication of the McKinney report), the American Atomic Energy Commission and the Federal Maritime Commission have jointly decided to put in hand immediately the preparation of a long-term programme for equipping merchant ships with nuclear engines in conditions which will make them commercially competitive.

¶ *Aircraft, locomotives and motor vehicles*

Nuclear propulsion presents particular difficulties in the case of aircraft. The provision of adequate protection against radioactivity is a great problem for the aircraft designer, for it is calculated that the minimum shielding that would be necessary would weigh something like 50 tons. It is doubtful, however, whether this disadvantage will long delay the use of nuclear

[1] McKinney report, p. 27.

power for the propulsion of military aircraft, the construction of which is not subordinated to financial considerations. It appears that the giant American seaplane *Seamaster* is to be equipped experimentally with a nuclear engine. It is reasonable to assume that if satisfactory technological results are obtained with military aircraft, the extension of nuclear propulsion to commercial aircraft will follow relatively quickly.

Nuclear propulsion for locomotives, although technically feasible, does not seem likely to become competitive in the very near future with the diesel engine, the use of which has become increasingly widespread during the past ten years. Research is, however, proceeding with a view to overcoming the technical difficulties which for the time being make the nuclear-powered locomotive uneconomic.

The use of nuclear power to drive motor vehicles presents even greater difficulties. The size of the reactor and the possible danger to the public from exposure to radioactivity (particularly in cases of road accidents) are serious obstacles to the development of nuclear-powered motor vehicles. For these reasons it is not believed in America that there will be much progress in this direction in the near future. This point of view appears to be shared by Soviet experts. A recent article in *Komsomolskaya Pravda* stated that, at the present stage of nuclear technology, an atomic touring car did not appear feasible. On the other hand, there are Soviet technicians who believe that, not many years hence, it will be possible to construct a nuclear-powered road vehicle which will be able to draw 4 or 5 trailers of 15–20 tons each, or three coaches carrying 50 to 80 passengers.

¶ *Space-heating and other applications of nuclear heat*

To give an idea of the vast scope for the use of nuclear energy for the heating of buildings, it is sufficient to mention that in the United States space-heating at present absorbs 30 per cent of the total power consumed in the country. The heat produced in a nuclear reactor can be used for direct heating purposes, as well as for the generation of electricity. Indeed, since as long ago as 1948 heat derived from an atomic pile at Harwell has been used to heat neighbouring buildings. The McKinney

report forecasts that heat of nuclear origin will probably compete eventually with heat from conventional sources for use in 'central heating systems for complexes of buildings' (so-called 'district heating'). As long ago as June 1955 the general manager of the American Institute of Boiler and Radiator Manufacturers stated at the annual meeting of that organization that it should be possible by 1958 to start producing home heating and cooling systems operated by 'baby' nuclear reactors.[1]

Nuclear heat could also find a wide field of application in industry, which consumes a vast quantity of electric power to produce the heat needed in manufacturing processes. It is calculated that American industry uses about 10 per cent of the country's total power output to supply the heat required in the production of metals, chemicals, cement, glass, paper, rubber, oil derivatives and other goods. It is estimated that these heat requirements will have tripled by 1980. Although preliminary experiments have shown that at present nuclear heat has no economic advantage over heat obtained from the conventional fuels, it is none the less believed that, with the progress that will undoubtedly take place in nuclear technology in the next few years, nuclear energy may be supplying 100 per cent of the total heat requirements of the United States by 1980.

The feasibility of utilizing the *radiation* given off by nuclear reactors is also being investigated. The research that is being carried out for the Atomic Energy Commission already holds out great prospects of the possibility of replacing ordinary heat by radiation heat in the chemical and food-preserving industries. The industrial importance of such a development can be readily appreciated when it is noted that a 1-watt light bulb gives out a barely perceptible amount of light or heat, whereas the energy emitted by a gamma-radiation source of the same power will kill a man in less than one hour!

It will be clear from this brief outline of the possible industrial applications of atomic energy that, with the rapid advance that

[1] See *The New York Times* of 2 June 1955, which gives a sketch of the projected atomic home heating and cooling system.

is taking place in nuclear science and technology, it is reasonable to assume that within ten years from now atomic energy may be performing all the services at present rendered by the conventional forms of energy. Admiral Strauss, Chairman of the American Atomic Energy Commission, who is obliged by the responsibilities of his office to be very cautious in his utterances, gave the following reply to a question put to him by the review *Newsweek* as to the likelihood of a rapid expansion of the peaceful utilization of atomic energy:[1]

'I'll stick with the conservatives for the next several years, but once we cross the hump of making electrical energy from atomic power competitive, I believe it will develop *more rapidly than many of the experts are now willing to predict.*'*

The pace at which the utilization of atomic energy will expand will of course depend on the cost of its production. This is a question which we shall now examine.

2. BRITAIN'S NUCLEAR PROGRAMME AND THE COST PER KILOWATT OF NUCLEAR POWER

Atomic energy development is more urgent in Great Britain than in the other industrialized countries, for in order to ensure the continued growth of her industrial output she will require an increase of about 40 per cent in energy supplies over the next fifteen years, whereas the expansion envisaged in coal production during this period is only 11 per cent, and, even then, at an investment cost of well over £1,000 million.[2] As regards electric energy in particular, the need for a new source is still more pressing, for in 20 years' time the demand for electricity is likely to be some $3\frac{1}{2}$ times greater than it is now, and it may already have doubled by 1965.[3]

It was therefore natural that Great Britain should be more prompt than the United States to embark on intensive research

[1] *Newsweek*, 20 February 1956, p. 34.

* Our italics.

[2] It is estimated that Britain's coal output should increase from nearly 225 million tons in 1956 to about 250 million tons in 1970. These figures were given by Sir Edwin Plowden, Chairman of the United Kingdom Atomic Energy Authority, at the 'Panel Discussions on Atomic Energy' organized by the World Bank in September 1956.

[3] 'A Programme of Nuclear Power', Cmd. 9389, London, February 1955.

with a view to the industrial utilization of atomic power, upon which indeed her whole economic future may directly depend. On the occasion of the publication of the British White Paper, 'A Programme of Nuclear Power', in February 1955, the then Minister of Fuel and Power, Mr. Geoffrey Lloyd, said that the programme 'offered the possibility of a new industrial revolution, with a continuing increase in productivity and in the standards of living'.

¶ *A revised and greatly expanded programme*

Inspired by this sense of urgency, Great Britain has pursued a policy which—except for certain reservations which might perhaps be made—has been coherent and consistent, with the result that, for the moment at least, she has the lead over all other countries in the matter of the industrial utilization of nuclear power.

The nuclear power programme announced in the above-mentioned White Paper of February 1955 was regarded at the time as 'daring'. It has however not only been put into execution but has in the meantime been accelerated and is being expanded to permit of the achievement of objectives three times more ambitious than those originally contemplated.

The following is a brief outline of the progress of atomic development in Great Britain:

The White Paper of February 1955 contemplated the construction within a period of ten years (1955–65) of 12 nuclear power stations, as follows:

(a) Two stations to be started about mid-1957 and to come into operation in 1960–1.
(b) Two further stations to be started in 1958–9 and to come into service by 1963.
(c) Four more stations to be started, possibly in 1960, and a further four 18 months later, the whole eight stations to be in operation by 1965.

It was anticipated that this ten-year programme, the cost of which might amount to £300 million, would provide a total

capacity of about 1,500–2,000 megawatts. This contribution to the covering of the country's energy needs would save five to six million tons of coal a year. It may here be noted that in 1955 the British Electricity Authority used 37 million tons of coal to feed its coal-fired power stations, the total generating capacity of which was 20.7 million kilowatts installed. Assuming the continued development of nuclear power production after the completion of the ten-year programme, the White Paper considered that the total nuclear power station capacity installed by 1975 might be of the order of 10–15 million kilowatts, in which case there would be a saving of some 40 million tons of coal a year.

The British Electricity Authority announced on 13 December 1956 the placing of contracts for the construction of the two first nuclear power stations, one at Bradwell in Essex and the other at Berkeley in Gloucestershire, to be followed by a third in southern Scotland. The first will have a net production capacity of 300,000 kilowatts and the second and third 275,000 kilowatts each. These three stations will thus have a combined capacity of 850,000 kilowatts, or twice as much as originally contemplated.[1]

On 5 March 1957, Lord Mills, the British Minister of Power, announced that Britain's nuclear power programme was being expanded to provide for the construction by 1965 of 19 nuclear stations with a total capacity of between 5 and 6 million kilowatts, as compared with the 12 stations with a total capacity of 1½ to 2 million kilowatts contemplated in the White Paper of February 1955. This expansion of nuclear generating capacity

[1] The following are a few details about the first of these three nuclear power stations:

This station will be of the same type as that at Calder Hall. It will have 360,000 kilowatts of installed capacity and will feed no less than 300,000 kilowatts of electricity into the national grid, thus saving a million tons of coal a year. It will cost £35 million to construct, or about £97 per kilowatt of installed capacity.

The station will have two reactors, each charged with 2,000 tons of graphite and 250 tons of uranium. The whole installation, including the steam plant, will have a total weight on the foundations of 70,000 tons. The shield giving protection against radioactivity will be nearly ten feet thick. Removal of used fuel elements and recharging will be possible while the reactor is working, so that these operations will involve no power losses. The steam will be channelled from the heat exchangers to the turbine hall, which will contain six 60,000-kilowatt turbo-electric generators. Operations will be controlled from control rooms, the special equipment of which will include television screens to facilitate supervision.

will bring the saving of coal up to 18 million tons a year. The cost of the revised programme is estimated at £1,460 million, as against the £300 million originally envisaged. Of the sum of £1,460 million, the construction of the stations will take £742 million and the nuclear fuel will cost £177 million. The balance of £541 million will be spent on nuclear research and development by the Atomic Energy Authority, which is at present spending £50 million a year for this purpose. In view of the present rate of development of nuclear science and technique, it seems not unreasonable to assume that by about 1975 Britain's electric power requirements (estimated at the equivalent of 100 million tons of coal) *will be entirely supplied by nuclear power stations.*[1]

¶ *The cost of nuclear power production*

Let us now examine the cost of the British nuclear power programme as a whole, and compare the estimated cost of the nuclear kilowatt-hour with the cost per unit of electricity generated in modern coal-fired stations.

According to the White Paper of February 1955 the overall cost of the provisional ten-year programme covering the construction of 12 nuclear power stations was estimated at £300 million. The stations will be built by private industry for the various Electricity Authorities, who will own and operate them. Technical advice on the planning of the nuclear plant will be supplied by the Atomic Energy Authority. The programme is to be financed out of the funds which the Electricity Authorities would in the normal course of events be investing in new coal- or oil-fired power stations during the ten years. Each of the first four stations will have two reactors. The White Paper put the cost of the initial charge of uranium for one of the early types of station at approximately £5 million, and assumed that re-charging would be necessary every 3–5 years, at about the same cost. The plutonium produced must be sold to the British

[1] This assumption finds some support in a cautious forecast made by Sir John Cockcroft in Paris in January 1957, when he suggested that by 1975 nuclear power might cover 70% of Britain's electricity requirements. If, however, the thermal efficiency of nuclear reactors can be improved—as seems quite probable in view of the rapid advance in nuclear technology—it may well be that by 1975 the nuclear power output will cover Britain's total electricity requirements.

Electricity Authority, which will buy it just as at present it buys coal. The Atomic Energy Authority will buy from the B.E.A. the nuclear fuel that has been 'irradiated' in the reactors as well as the radioisotopes produced in the nuclear reaction process.

The following table shows how the estimated cost of the original nuclear programme, i.e. £300 million, was arrived at, a figure which is equivalent to between £150 and £200 per kilowatt of capacity installed, compared with £60 per kilowatt for a modern coal-fired station:[1]

COST OF THE ORIGINAL BRITISH NUCLEAR POWER PROGRAMME

	Building *Starting*	*Completed*	*Power Megawatts*	*Total cost £ million*
2 power stations	1957	1960–61	100–200	30–35
2 ,, ,,	1958–9	1963	100–200	30–35 +
4 ,, ,,	1960	1963–64	Combined rating of more than 1,000 megawatts	125
4 ,, ,,	1961–2	1965		
Building cost of 12 power stations	10-year programme		1,500–2,000	200
Uranium . .	10 years' supply		. .	40
Ancillary equipment . .	,,	,,	. .	30
Prototype expenditure . .	During the 10 years		. .	30–40
Total cost of programme .			.	300

In the case of the first station, the contract for the building of which was placed in December 1956, the construction cost per kilowatt of capacity installed will, however, be only £97, that is to say much less than the original estimate of £150–200, the reason being that this station will have 360,000 kilowatts of installed capacity, instead of 150,000 kilowatts as contemplated

[1] *The Economist*, 19 February, 1955.

in the programme of February 1955. In spite of this great reduction in the construction cost per kilowatt of capacity, £97 is still appreciably greater than the cost per kilowatt of capacity (£60) in the case of a coal-fired station.

¶ *The cost of generating nuclear power*

Let us look first at the cost of the fuel. This depends on:

(a) the cost of the raw material—uranium;
(b) the cost of treating this material; and
(c) the level of irradiation, that is, the amount of heat that can be got from each ton of fuel in the reactor before it has to be taken out (otherwise known as the 'burn-up').

It was expected that in the first nuclear power stations it would be possible to extract from every ton of the uranium fuel a quantity of heat equivalent to that obtainable from 10,000 tons of coal. At present a thermal power station in Great Britain pays £4 a ton for the coal it consumes, so that, on the basis of this equivalence, the amount of heat that could be obtained from 10,000 tons of coal costing £40,000 could be obtained from 1 ton of uranium, the cost of which, including treatment, is at present put at not more than £20,000. It now appears, however, that as a result of recent technical progress, it is already possible to obtain from uranium a heat output at least two to three times greater than that assumed in the above-mentioned equivalence.

In the light of the technical situation at the beginning of 1955, the White Paper stated (without giving details) that the cost of power from the first nuclear stations should work out at about 0.6d. per unit, or about the same as the cost per unit of electricity generated in a modern coal-fired station. On the other hand, in a paper presented at the Geneva atomic conference, Mr. J. A. Jukes, of the United Kingdom Atomic Energy Authority, arrived at the following estimates of capital and operating costs for nuclear power stations of the type contemplated in the British White Paper:[1]

[1] Document P/390: 'The Cost of Power and the Value of Plutonium from Early Nuclear Power Stations'.

COST OF GAS-COOLED GRAPHITE-MODERATED NUCLEAR POWER STATIONS
(150 M.W. output)

	Capital cost (*£ million*)	*Annual cost* (*£ million*)	*Cost of electricity at 80% load factor* (*pence per kwh*)
Capital and Overhead			
Reactor items	7.5	0.68	
Other plant	11.3	0.69	
Total construction	18.8	1.37	
Cost of initial fuel charge at £20,000/tonne U	5.0	0.20	
Total capital cost	23.8	1.57	0.36
Operating			
Site operating costs		0.26	
Cost of replacement cartridges at £20,000/tonne U		1.46	
Total operating cost		1.72	0.40
Total *gross* cost		3.33	0.76 (= 9 mills)

This calculation thus arrived at a *gross* cost of 0.76d. (= 9 mills) per kilowatt-hour for electricity from the first nuclear power stations. To arrive at the *net* cost, credit must be allowed for the value of the fissile by-product, plutonium. It is the commercial value of plutonium which will finally determine the net cost of the nuclear kilowatt-hour. Mr. Jukes assumed that, 'on a cautious assessment', this value may vary between £5 and £10 a gram, and on the basis of these two extremes, he calculated that the net cost of nuclear power per unit should be between 0.59 and 0.42 pence (or between 7 and 5 mills). According to a statement made recently by Sir Edwin Plowden, in estimating the cost of power from the first nuclear power stations it is reasonable to assume a credit for the plutonium

by-product equivalent to about 0.1d. per unit of electricity sent out.[1]

¶ *Prospects of a reduction in the cost of generating nuclear power*

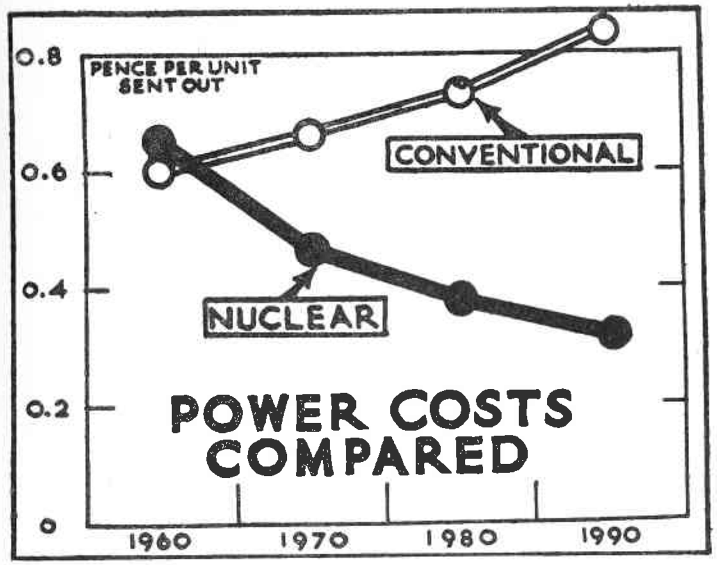
Since the White Paper first estimated that the cost of production per kilowatt-hour should be the same for the early nuclear power stations as for the modern coal-fired stations (i.e. 0.6d., or 7 mills), the comparison has moved in favour of nuclear power, for two reasons:

(a) the cost of nuclear power will fall because it is now proposed to build power stations with an installed capacity of 300,000 kilowatts or over, as against a capacity of 150,000 kilowatts originally contemplated;
(b) the technical progress achieved since the White Paper was issued will make it possible to double or even treble the calorific yield of uranium.

In view of the improvements in nuclear technique, Sir John Cockcroft believes that by 1960 the cost of nuclear power should have fallen appreciably below the cost of power from coal-fired stations, and that within ten to fifteen years from now it may be possible to generate nuclear power at a cost of about 0.3 to 0.4 pence (4 to 5 mills) per unit.[2]

In a lecture to the Royal Swedish Academy of Engineering Sciences, Stockholm, on 15 March 1957, Sir Christopher Hinton said that the cost per unit of nuclear electricity sent out into the national grid could be expected to fall from 0.66d. in 1960 to 0.47d. in 1970, to 0.38d. in 1980 and to 0.32d. in 1990. Estimated comparable costs per unit of electricity from conventional oil or coal-fuelled power stations were quoted by Sir Christopher as follows: 0.60d. per unit in 1960, 0.67d. in 1970, 0.73d. in 1980 and 0.84d. in 1990. The significance of these two divergent cost trends is graphically illustrated by the following diagram (reproduced from *The Financial Times* of 16 March 1957).

[1] International Bank for Reconstruction and Development: Informal Panel Discussion on Atomic Energy in Economic Development, 27 September 1956.
[2] Op. cit.



It is clear, therefore, that nuclear power is already economic, and that the current sent out from Great Britain's first nuclear power stations will already be cheaper than that from the coal-fired stations.[1]

¶ *Is the dual nature of Britain's nuclear power programme likely to retard industrial development?*

Great Britain at present leads the world in the industrial utilization of nuclear energy, and there would seem little risk of her being outdistanced by any other country in this sphere if she concentrated all her efforts on the production of nuclear power for purely peaceful purposes. Instead however of remaining outside the nuclear armaments race, in which the United States and the Soviet Union are competing at enormous cost, Britain, still actuated by the 'Great Power complex', has

[1] Referring to the cost of the revised programme, Lord Mills stated that generating costs in the three stations already ordered were expected to be slightly more than in new conventional stations, taking into account capital costs as well as operating costs. With improvements it was hoped that ultimately the cost of the nuclear stations would be less than those of conventional stations. (*The Times*, 6th March 1957.)

decided that she too must engage in the development and production of thermonuclear weapons. She is thus using an appreciable part of her supplies of fissile material for military purposes. The first four British nuclear reactors (those at the Calder Hall and Chapel Cross stations, which are not regarded as forming part of the ten-year programme) have been constructed primarily to produce the plutonium necessary for thermonuclear weapons. The first of these four reactors ('PIPPA') was put into operation at Calder Hall on 17 October 1956. It has an installed capacity of 90,000 kilowatts, and performs the double function of producing electricity for general use and plutonium for military purposes.[1]

According to a report in the *Manchester Guardian* of 27 February 1956, it was estimated that Great Britain then had a stock of between 2,500 and 4,000 bombs. The report added that she would have sufficient plutonium and uranium for the production of from 300 to 500 thermonuclear bombs and about 600 atomic bombs a year.

The future will show whether this dual (pacific and military) character of the nuclear programme will, or will not, contribute to the strengthening of Great Britain's position as a Great Power. It can, however, already be said that it will be difficult to maintain this duality if and when other countries, and in particular Germany and Japan, enter the world atomic market. These two countries are placed at an advantage by the treaty stipulation which prohibits them from joining in the armaments race, for they can now enter upon the peaceful exploitation of atomic power with undivided energy and with the most modern industrial equipment, to the great enhancement of their competitive capacity.

It is interesting in this connexion to recall a warning given by Sir Anthony Eden in May 1955. Speaking of the great opportunities of the new scientific age, Sir Anthony said:

'Our competitors are hard-working and ambitious. They have grasped the opportunities of today and they are out to get all the trade they can . . . The more we succeed in marrying science

[1] The construction of 'PIPPA' took about 3½ years and cost £16,500,000. For a complete description of this dual-purpose plant, see Kenneth Jay's *Calder Hall: The Story of Britain's First Atomic Power Station*, London, 1956.

to industry, the better we will be placed to compete with other countries. Our lives depend on this.'

Will Great Britain—already handicapped by a shortage of steel[1]—be in a position to cope with the constructional work involved in the new nuclear programme announced in March 1957, and at the same time continue to produce atomic and thermonuclear weapons? Will she not be compelled to re-examine the longer-term consequences of her present nuclear policy? Would it not be in Britain's best interests to leave pre-occupation with the military aspects of atomic energy to the United States and the Soviet Union, and to concentrate on maintaining her lead in the industrial exploitation of the atom?

3. THE AMERICAN NUCLEAR PROGRAMME AND ESTIMATES OF THE COST OF NUCLEAR POWER PRODUCTION

Notwithstanding the enormous progress made in the development of atomic and thermonuclear weapons, it was not until 1954 that the United States adopted a five-year programme for the industrial exploitation of atomic energy.[2]

This programme, although it has been somewhat expanded in the meantime, is still quite modest in relation to the nuclear resources mobilized by the United States to secure that country's predominance among the world's Great Atomic Powers, and it lags far behind the British programme for the development of the industrial use of atomic energy. It may be noted in this connexion that the capital investment envisaged in the British programme for the construction of nuclear power stations in the years 1955–65 is equivalent to over $4,000 million, as against $700 million contemplated by the Americans for their five-year programme.[3]

[1] Commenting on the recent revision of the nuclear power programme, *The Financial Times* remarks (15 January 1957): 'At present one of the limiting factors in the expansion of the nuclear power programme is the supply of steel plates.'

[2] The main features of the 1954 programme are described in a document presented at the Geneva atomic conference (Document No. 11 of 10 August 1955), entitled 'Background Information on Atomic Power Development in the United States'.

[3] This latter figure relates only to expenditure on the building of nuclear power stations. About half the American expenditure of $700 million will be met by private industry. In addition, the Atomic Energy Commission makes yearly allocations for developing and constructing experimental power reactors. For this purpose it spent $28 million in the financial year 1955, $52 million in 1956, and will spend $84 million in 1957. (See *The New York Times* of 13 January 1957.)

According to statements made by Admiral Strauss, Chairman of the American Atomic Energy Commission, and by Mr. W. Kenneth Davis, one of the Commission's leading technical experts, when taking part in the 'Panel Discussion' organized by the World Bank in September 1956, the United States' present nuclear programme contemplates:

(a) the construction by private industry of nuclear power stations with a total capacity of 700,000 kilowatts;
(b) the construction by the Atomic Energy Commission and private industry, jointly, of nuclear power stations with a total capacity of 400,000 kilowatts;
(c) the construction of 9 research reactors of different types, with the object of determining the most economically satisfactory method of producing utilizable nuclear power.

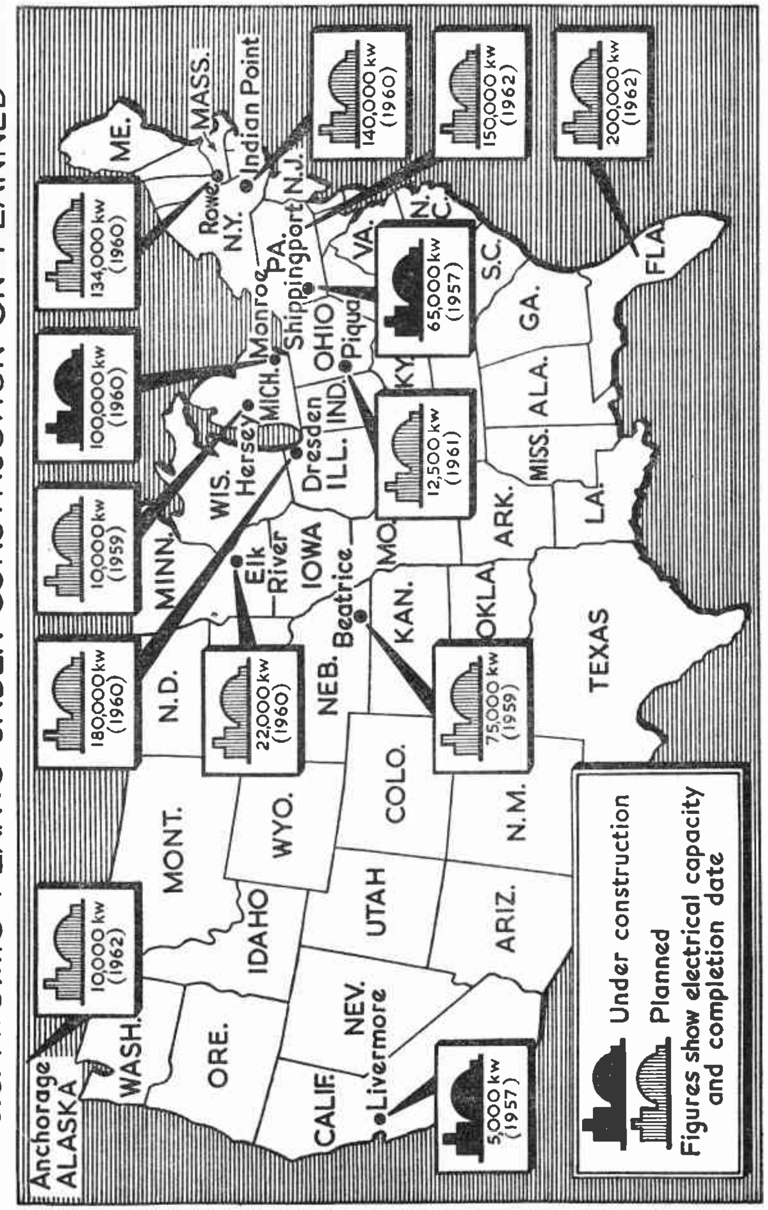
The total number of power stations contemplated is 13. The largest, with a capacity of 200,000 kilowatts, is to be ready by 1962. Of these 13 stations only 3 are as yet under construction. The first, at Shippingport in the Pittsburgh area, with a capacity of 65,000 kilowatts, will be completed in 1957, as will also the second, at Livermore, California, with a capacity of 5,000 kilowatts. The third, at Monroe, Michigan, is expected to come into operation in 1960. The locations of the 13 stations now under construction or planned are shown on the following map, which we reproduce by courtesy of *The New York Times.*

It will be seen from the details given on this map that the stations which should be in operation by 1960 are to have a combined capacity of about 730,000 kilowatts, as compared with the British and Soviet targets for that year of 2 million and 2–2½ million kilowatts, respectively.

¶ *Are other countries ahead of the United States?*

The figures given in the preceding paragraph indicate that, as regards stations under construction or planned, the United States is being out-distanced by the Soviet Union and Great Britain in the development of the industrial utilization of nuclear power. The Americans themselves do not appear to

U.S. ATOMIC PLANTS UNDER CONSTRUCTION OR PLANNED



share this view. Preoccupied with the present rather than the future, they are confident as to the superiority of their country in this domain. In reply to a questionnaire put out by the magazine *U.S. News & World Report* in January 1957, two senators who are regarded as competent to speak on nuclear matters affirmed that the United States is in advance of other countries. Thus, to the question: 'Is it your opinion that the United States is ahead of the Soviet Union in industrial uses of atomic and hydrogen potentials?', Senator Clinton P. Anderson, Chairman of the Joint Congressional Committee on Atomic Energy, replied:[1]

'I would assume that we may be ahead of them at the present'; but he added: 'I think I would also have to say that I believe Russia is gaining on us very rapidly, and Britain is gaining on us still more rapidly.'

In contrast to this qualified assertion by Senator Anderson, the reply given by Mr. W. Sterling Cole, a member of the Joint Committee on Atomic Energy, is quite categorical as to America's lead:

'It's a demonstrated fact that we are far ahead—both in the weapons phase of atomic energy and in the industrial, peacetime application of it.'

After adding that the Soviet Union's small nuclear power station is really more of a research reactor, not a commercial reactor, and that the nuclear power stations under construction in Great Britain will serve the dual purpose of generating industrial power and producing nuclear material for weapons, Mr. Cole concludes:

'So we are ahead in my opinion—I've no question or doubt in my mind of our superiority.'

The programmes that have been announced do not, however, bear out this categorical statement. Although the Americans may be ahead in the sphere of nuclear research, the same cannot be said of them as regards nuclear power production. What is the explanation of America's relative backwardness in this respect? In our view it is as follows:

Firstly: The United States still possesses ample resources for

[1] *U.S. News & World Report,* 11 January 1957, p. 125.

production of the conventional forms of energy, and consequently does not regard the construction of nuclear power stations as an urgent necessity. Admiral Strauss, Chairman of the A.E.C., made the following statement in September 1956:

'It is fortunate that our reserves of coal, oil and gas are recoverable at comparatively low cost, and are in such quantity that we have time to investigate and experiment with the many types of power reactors.'[1]

Secondly: Under the law of 1954 it was contemplated by the American government that the industrial development of the atom should be entrusted to private enterprises. But the private enterprises—which, in our opinion, are not in any case in a position to undertake the exploitation of this gigantic source of energy—are not exhibiting any great eagerness to speed up the construction of nuclear power stations. The vastness of the capital expenditure entailed, the rapid advance of nuclear science and the divergence of views as between private enterprise and the Atomic Energy Commission, all tend to slow down development of the industrial application of nuclear power.

Thirdly: The general public is insufficiently informed on the subject of the peaceful utilization of atomic energy, and of the extent to which it has already been developed in a number of other countries.

It is curious to note the persistence in the United States of the view that atomic power cannot become competitive in that country before 1965. This view was expressed in a report published by a group of nine experts on 31 January 1956; and in the McKinney report, published on the 30th of that month, we read: 'If one thing is clear, it is that much must still be done before atomic power becomes widely commercially competitive.' Admiral Strauss, Chairman of the Atomic Energy Commission, has expressed an identical opinion, and, in replying to the questionnaire mentioned above, Senator Clinton P. Anderson said: 'It (atomic energy) cannot become competitive before 1965 and probably not until 1975.'[2]

[1] International Bank for Reconstruction and Development: Informal Panel Discussion on Atomic Energy in Economic Development, 27 September 1956.

[2] *U.S. News & World Report,* 11 January 1957, p. 125.

And yet the American experts cannot be ignorant of the developments in Great Britain and the Soviet Union in the domain of the industrial exploitation of atomic energy. Britain is already able to produce nuclear power at a cost of about 7 mills per kilowatt-hour. In the light of the present state of nuclear science and technique and the astounding rate at which they are progressing, is it conceivable that it will take the United States ten years to bring the cost down to 5.9 mills per kilowatt-hour, a level at which nuclear power would be commercially competitive?[1] Even at 7 mills, it would already be competitive in certain regions of the country.[2]

Even if nuclear power were not competitive in the United States, could the Americans afford not to exploit to the full its industrial potentialities? What would be the ultimate effect on the United States' competitive capacity, and on her ability to fulfil the role which she has assumed on the international plane, if she failed to undertake a vast programme for the development of the industrial utilization of nuclear power?

But let us look in the first place at some estimates of the cost of production of nuclear power in the United States.

¶ *Making nuclear power competitive in the United States*

The development of the industrial use of nuclear power in the United States—a country which has an abundance of the traditional sources of energy—will be determined by the cost factor to a greater extent than will be the case in most other countries. According to a calculation made by the Federal Power Commission, the average cost of electricity produced in the United States in 1951 (i.e. from conventional sources) was 7.4 mills per kilowatt-hour. This calculation was based on the total output of all plants, whatever their size or age. On one-fifth of this output, the production cost worked out at over 6.9

[1] The Federal Power Commission has calculated that the cost of half the power generated from the conventional sources in the United States in 1951 was 5.9 mills per kilowatt-hour.

[2] 'But it is competitive now here in this country,' said Mr. Sterling Cole, member of the Joint Congressional Committee on Atomic Energy, 'in certain areas where the power from conventional fuels is exhorbitant or unusually high. Out in the Minnesota-Michigan area—up in there—conventional power is very high. Up in Alaska it's extremely high. In some parts of New England, power rates are high.' (*U.S. News & World Report*, 11 January 1957, p. 126.)

mills per kilowatt-hour, and on one-half of it at 5.9 mills. This means that, for nuclear power to be competitive in 20 per cent of the American market, it must not cost more to produce than 6.9 mills, and that for it to be competitive in 50 per cent of the market its cost must not exceed 5.9 mills.

The question arises, therefore, whether in these conditions nuclear power can, within the next few years, be made competitive with power from the conventional sources.

Since the scientist first succeeded in disintegrating the atom and producing usable nuclear power, a number of estimates have been made in the United States of the probable cost of the nuclear kilowatt-hour. Among the earlier estimates mention should be made in particular of those of the Cowles Commission for Research in Economics, of the University of Chicago, which published in 1950, under the direction of Sam H. Schurr and Jacob Marschak, a most interesting study of the economic aspects of nuclear power.[1] Other interesting calculations of more recent date are those made by Mr. Francis K. McKune, General Manager of the Atomic Department of the General Electric Company, and presented by him to the Atomic Industrial Forum in 1954. We shall not analyse these estimates—which are optimistic as to the possibility of producing nuclear power at a competitive price—since they are largely based on theoretical data.

It was not until the Geneva atomic conference that somewhat more concrete American data became available. We shall refer in particular to the report by James A. Lane, of the Oak Ridge National Laboratory (P/476: 'Economics of Nuclear Power'), and to that by W. Kenneth Davis, of the U.S. Atomic Energy Commission (P/477: 'Capital Investment Required for Nuclear Energy'). These two reports were most informative on the subject of cost.[2]

[1] *Economic Aspects of Atomic Power*, published for the Cowles Commission for Research in Economics by Princeton University Press, 1950, p. 23 et seq.

[2] The question of nuclear costs in America is also dealt with in the following documents presented at the conference:

P/758, J. M. Kay: 'The Role of Nuclear Energy in Relation to other Methods of Electricity Generation'.

P/391, J. M. Hill and S. W. Joslin: 'The Capital Investment for Nuclear Energy'.

P/475, K. M. Mayer: 'The Economic Potential of Nuclear Energy'.

James A. Lane's paper examined this question from various angles. He first quoted cost calculations made by the American Atomic Energy Commission and by certain private enterprises. The capital cost varied, depending on the type of reactor used and its capacity, from $183 to $450 per kilowatt of capacity. Corresponding power cost estimates ranged from 4 to 10 mills per kwh of electricity produced. The main problem, said Mr. Lane, was not to estimate the capital cost of the nuclear plant, but to assess the incidence of various factors on the cost of production per kwh.

The most important of these factors were:

(a) the effective useful life of the plant;
(b) operating and maintenance costs;
(c) the net fuel cost, after adding charges due to fuel inventories, fuel burn-up and fuel reprocessing, and subtracting the value of the fissile material produced in the reactor.

Emphasizing that the figures quoted by him were based purely on laboratory calculations, Mr. Lane defined the conditions and assumptions necessary to obtain power costs of 4 mills, 7 mills and 10 mills per kwh, respectively.

4 mills per kwh

To obtain electricity at 4 mills per kwh, it would be necessary to achieve very favourable operating conditions, such as a 90 per cent load factor and operating and maintenance costs as low as 0.5 mill per kwh. Further, the capital cost of the plant must not exceed $180 per kilowatt of capacity and net fuel costs must be of the order of 0.10 mill per kwh.

7 mills per kwh

This price pre-supposed average capital costs and less severe operating conditions (i.e. an 80 per cent load factor and 1.0 mill per kwh operating and maintenance costs). The net cost of fuel must be between 0.5 mill and 1.2 mills per kwh.

10 mills per kwh

Power should be producible at 10 mills per kwh on the basis of a 70 per cent load factor and operating and maintenance

costs up to 1.2 mills per kwh. Capital cost of the plant might be as high as $280 per kilowatt of capacity, and the net cost of fuel 1.7 mills per kwh.

Projecting these data on to the plane of the estimated growth in the consumption of electric power, Mr. Lane arrived at the conclusion that if nuclear power were produced at 10 mills per kwh, its potential market in 1975 might be assessed at about $300 million; and that this potential should increase to about $3,800 million at costs below 7 mills per kwh, and to $25,000 million at 4 mills per kwh. He added that on the basis of a cost of natural uranium of $40 per kilogram, and a credit of from $15 to $30 per gram of fissile material produced in the reactor, the possibility of achieving a nuclear power cost of about 4 to 5 mills per kwh seemed good. These calculations found support in a paper presented at the conference by Mr. K. M. Mayer, who believed that if the cost of the nuclear kwh were in the neighbourhood of 10 mills, the consumption of nuclear power would be insignificant, but that it might reach the modest figure of 20 thousand million kwh by 1960 if the cost were 8 mills, and that it would increase 'dramatically' if the cost fell below 7 mills.[1]

In the light of all available economic and technical information, Mr. Lane regarded the outlook for the production of nuclear power on a large scale in the United States as very promising. 'If anticipated nuclear plant costs and operating conditions, such as long life of equipment, high load factor and efficient fuel utilization can be realized, such plants will produce electricity at prices well below the average for conventional fuels.' Mr. Lane concludes: 'There is good indication that these necessary advances will be achieved in the next five to ten years through the vigorous reactor development and nuclear power plant construction programme now under way.'[2]

¶ *The various elements in production costs*

Mr. W. Kenneth Davis, whose paper dealt more especially

[1] Document P/475, p. 23. According to calculations made by the American Atomic Energy Commission, electric power output in the United States should reach 1,400 thousand million kwh by 1975.

[2] Document P/476, p. 25.

with the problem of financing nuclear power station projects, gave data which appeared to confirm the optimistic view that nuclear power would soon be economically competitive with the conventional sources of power. He calculated that at that time the total investment cost for all parts of a large power reactor system would be $350 per kilowatt of capacity. The following were the various components which entered into this calculation:[1]

	Investment cost per kilowatt of capacity (in dollars)
Exploration, mining, ore concentration	1
Purification and reduction	1 to 3
Enrichment	40 to 80
Fuel element fabrication, cold	5
Fuel element fabrication, radioactive	15
Heavy water manufacture	30 to 50
Zirconium manufacture	1 to 2
Nuclear reactor power plant	210 to 250
Fuel inventory	20 to 40
Containment	10 to 20
Fuel processing	30 to 60

Mr. Davis remarked, however, that it was likely that for 'the next generation of nuclear power plants' investment cost would be less than $350 per kilowatt of capacity and that, indeed, technological developments might quite possibly reduce the figure to $250, which 'would be closer to economic competition and seems attainable for reactors that will be under construction 5 or 10 years from now.'

¶ *Will the United States' atomic policy be in the country's best interests?*

The general picture as regards the cost of nuclear power does not appear to have been greatly changed by such data as has been published since the Geneva conference. In the World Bank's 'Panel Discussion' (September 1956), neither Admiral Strauss nor Mr. Kenneth Davis went into details on this question. While they were very optimistic on the subject of nuclear development, these two leading members of the Atomic

[1] Document P/477, p. 17.

Energy Commission did not consider that nuclear power stations would be competitive with the conventional stations much before 1965. As we have seen, this view is shared by other nuclear specialists in the United States.

The direct consequence of this theory is that the United States does not for the moment contemplate embarking on a vast nuclear power programme, but is concentrating mainly on the construction of prototype reactors and leaving it to private industry to decide when the time is ripe for the construction of nuclear power stations. In this connexion it is interesting to note the following statement made in the course of the 'Panel Discussion' by Admiral Strauss, who, it will be remembered, is the Chairman of the Atomic Energy Commission and whose remarks are therefore significant:

'To engage in a crash program of atomic power plants in the United States, based on the present state of our knowledge would, we think, be neither prudent, nor would it fulfil our obligation to develop the atom for peaceful purposes.'

With all the deference due to Admiral Strauss, we venture to doubt whether he is entirely right on this point. In the first place the opinion he expresses does not appear to be consistent with the present state of nuclear research; and, further, it does not seem to us to be consonant with the international role that the United States must play in the nuclear sphere. Such an attitude is calculated to cause profound discouragement among the underdeveloped peoples of the world, who are looking to the great atomic nations to realize as rapidly as possible the promises of this new industrial revolution.

We base our opinion in this matter on three main arguments:

1. In the light of the British data as to cost (which cannot be so widely different from the American calculations), it should be possible to produce nuclear power in the United States at a cost of about 7 mills per kilowatt-hour, at which figure it would already be competitive with power from the conventional sources.

2. The price of technical progress is continual experiment, unhampered by undue subordination to financial considerations. A concrete example is the preliminary research and experimenta-

tion which has culminated in the building of the Calder Hall station and will immensely facilitate the carrying out of the earlier stages of the British ten-year nuclear power programme. While recognizing the value to be derived from the construction of a series of prototype reactors—which is the main feature of the U.S. Atomic Energy Commission's present policy—one cannot but believe that the absence of an extensive programme of nuclear power station construction must limit the possibilities of technical and scientific progress.

3. The American view that the present state of technique does not permit of any striking development of the industrial use of nuclear power may be valid if the problem is regarded solely from the standpoint of private enterprise. A private undertaking must of course be 'prudent'; its capital investment is inevitably determined by purely financial considerations. The same is not the case, however, with the state, whose activities must always be guided by considerations (social, scientific and political) of a wider nature, or in other words by considerations of 'public interest'.

Now, the United States, with a budget in excess of $83,000 million, of which military expenditure accounts for some $43,000 million (including $12,000 million devoted to the manufacture of atomic and thermonuclear weapons), surely cannot plead that it is unable to find the few additional hundred million dollars which could make an inestimable contribution to the progress of nuclear science and technique and to the prosperity not only of the United States but of all the peoples of the world.

¶ *Two major bottlenecks: 'denationalization' of the atom, and censorship*

'Denationalization' of the atom and atomic censorship are two factors which are at present delaying the development of the peaceful use of atomic energy.

The exploitation of this gigantic new source of power will necessitate the provision of such a vast amount of capital that the task cannot be shouldered by private enterprise, whose primary objective is a quick return on its investments. The

first result of the 'denationalization' has been to retard the industrial development which atomic energy makes possible. We shall have occasion to refer later to other unfortunate consequences. There appears to be a growing awareness in the United States that this 'denationalization' is one of the causes of the delay in the application of atomic power to peaceful uses. Thus, the McKinney report, while recommending the participation of private enterprise in atomic development, is careful to add this warning: 'Although private participation in this program is desirable, it should not be obtained at the cost of delay.' On 6 January 1957 the Atomic Energy Commission called for new proposals from private and public interests on the construction of nuclear power plants. Admiral Strauss thought it necessary, however, to couple the invitation with a statement that if industry did not respond with acceptable proposals within a reasonable time, the Commission would ask Congress for money to build the plants itself.[1]

Further, the drastic security regulations, and the serious penalties for their infringement, in force in the United States in regard to 'national defence' and 'nuclear science' data, tend to prevent free discussion among men of science—even on nuclear questions which have no possible security implications—because of the risk of committing an indictable 'indiscretion'. Nuclear secrets are no longer the monopoly of the United States, and today, when all countries are actively endeavouring to develop the pacific use of nuclear power, the effect of this severe censorship can only be to delay scientific progress. 'We need the benefit of all the scientists in the United States,' says Senator Clinton P. Anderson, Chairman of the Joint Congressional Committee on Atomic Energy, 'if we're to stay in the race, and many of them are precluded from participating because of what I regard as foolish secrecy requirements.'

It seems obvious, therefore, that if the United States desires to gain or maintain supremacy in the nuclear field, it will have to revise its policy in two major respects:

(1) the state must assume responsibility for the industrial exploitation of nuclear energy, and adopt a programme

[1] *The New York Times* (International Edn.), 7 and 13 January 1957.

of nuclear power plant construction commensurate with the country's vast economic resources and strength; and
(2) the present nuclear censorship must be modified: in other words, data relating to the latest advances in the pacific utilization of nuclear power must be made freely accessible; and there must be complete freedom of discussion among nuclear specialists, for only then will optimum progress in nuclear science and technique be assured.

4. THE NUCLEAR PROGRAMME OF THE SOVIET UNION

As we have already seen, the Soviet Union was the first country in the world to possess a nuclear power station for the generation of electricity. Although this station had a capacity of only 5,000 kilowatts, the Soviet Government's announcement of its opening on 27 June 1954 was sensational news at that period. It was simultaneously announced that larger nuclear power plants, with a capacity of from 50,000 to 100,000 kilowatts, were being planned.

With the opening of Britain's 90,000 kilowatt nuclear power station at Calder Hall on 17 October 1956, the Soviet Union lost its lead in the industrial utilization of atomic energy. Apart, however, from the further plants announced as under contemplation in June 1954, the Soviet government has made provision in its sixth Five-Year Plan (1955–60) for the construction of nuclear power stations, with a combined capacity of from 2 to 2½ million kilowatts, as the first phase of a long-term nuclear programme.

Here are some details from Soviet sources about this programme:[1]

1. The nuclear power stations to be constructed during the period of the Five-Year Plan (1955–60) will still be of an experimental character, their main purpose being to discover the most rational and economic system for the transformation of

[1] The programme was first announced in February 1956 when the directives for the sixth Five-Year Plan were issued. At the 20th Congress of the Russian Communist Party, the academician Kurchatov gave some details of the generating capacities of the nuclear power stations under construction. Supplementary information was given by the academician A. Alexandrov in an article entitled 'La construction de centrales atomiques', published in *Etudes Soviétiques*, No. 105, of December 1956.

nuclear energy into electricity. For this reason the plants will be of three different types:

> Two will use enriched uranium as fuel, and ordinary water at high pressure as both moderator and coolant.
> A third will work on enriched uranium, with graphite as moderator and water as coolant.
> A fourth will use natural uranium, and will have heavy water as moderator and gas as coolant.

2. The nuclear power stations now under construction will be of high capacity (200,000, 400,000 and 600,000 kilowatts).[1] For this reason use will not be made of graphite-moderated gas-cooled reactors (the system adopted in France and Great Britain) which, according to the Soviet nuclear scientists, cannot attain a capacity of 200,000 kilowatts.

3. Other plants are being constructed, with various types of reactors (sodium-cooled, homogeneous and boiling-water reactors) to generate some 50,000 kilowatts.

4. Of the large nuclear power stations now under construction, two are in the Ural region and one near Moscow. According to Kurchatov, the combined capacity of the two Ural stations will be 1,000,000 kilowatts and the Moscow station will have a capacity of 400,000 kilowatts.

The Soviet authorities believe that as a result of this great nuclear power programme—which aims at providing a total nuclear power production capacity of 2½ million kilowatts by 1960—they will have ascertained which will be the most suitable types of power station for the future development of atomic energy.

¶ *The cost of nuclear power in the Soviet Union*

Soviet delegates at the Geneva atomic conference were in a position to furnish costs data based on about a year's practical experience of the operation of a 5,000 kilowatt nuclear power station. In their report, the Soviet experts, D. I. Blokhintsev and

[1] Radio-Moscow announced on 28 January 1957 that the Soviet Union had begun construction of five nuclear power stations, each with a capacity of between 400,000 and 600,000 kilowatts, to come into service between the end of 1958 and 1960.

A. Nikolayev, discussed this plant from both the technical and the economic aspect. They stated that the cost of electricity generated by this first nuclear power plant was 'appreciably higher than the average cost per kilowatt-hour of power from the large thermal stations in the U.S.S.R.', which in 1953 was about 15 copecks.[1] They added, however, that the cost of this nuclear power was competitive with that of thermal power from stations with a capacity of from 1,000 to 5,000 kilowatts. The high level of cost in the case of this first nuclear power station was primarily attributable to the following factors: (a) in view of the small size of the plant, fuel elements needed to be prepared only in small quantities; (b) slightly enriched uranium had to be used; (c) more personnel were needed per unit of power produced than would be the case with larger plants; (d) construction costs were unduly increased by the precautions provided against the radiation hazard—precautions which subsequent experience had shown to have been excessive, so that for future stations expenditure on this item could be reduced without danger.

A nuclear power station of 100,000 kilowatts capacity would, the Soviet experts stated, be comparable, as regards overall cost, with a coal-fired plant of equal capacity. There were, however, certain advantages in favour of the nuclear power station. In the first place, it would require only one-third to one-half the personnel needed for the thermal power station, and its consumption of energy would be smaller. Further, the construction and general equipment of a nuclear power station was less costly than that of a thermal plant of equivalent generating capacity. The resultant saving in the case of the nuclear power station would offset the considerable expense entailed in providing protection against radiation.

The Russian delegates at the Geneva conference affirmed, however, that a nuclear power station would already be more profitable than a coal-fired station in regions situated far from coal mines, or than a station operating on low quality fuel.

Soviet nuclear experts believe that the power produced in the new plants contemplated in the sixth Five-Year Plan will not be

[1] Document P/615, p. 21.

dearer than that generated by the present thermal power stations.[1]

¶ *Differences between cost factors in the U.S.S.R. and those in other countries*

According to certain Soviet experts, the production cost per kilowatt-hour of nuclear power should be lower in the U.S.S.R. than in the Western countries. In an article in *Komsomolskaya Pravda*, Professor V. Romadin says that the reason for this is that in the U.S.S.R. interest on the capital investment does not have to be taken into account in the calculation of production cost.[2]

In private enterprise the servicing of invested capital and the entrepreneur's profits bulk large in the calculation of production costs. In a paper presented at the Geneva conference, on the financing of a nuclear power industry, W. Kenneth Davis compared the current levels of fixed charges against capital investment in the United States for the following types of enterprise: (a) a private enterprise which aims at showing large profits; (b) a private enterprise whose rates of profit are regulated by the government; and (c) a plant which is entirely financed by the government at a low rate of interest, does not distribute profits and is exempt from taxation. He calculated that in case (a) fixed charges would amount to 49.5 per cent of the capital invested, in case (b) to 14.03 per cent and in case (c) to 5.27 per cent. Mr. Davis went on to examine the incidence of fixed charges on the cost of power from a nuclear plant costing $250 per kilowatt of capacity and producing 7,000 kwh per annum per kilowatt of capacity. If the fixed charges for this plant amounted to 14 per cent of the capital invested (case b) they would work out at 5.0 mills per kwh, but this figure would fall to 1.87 mills per kwh if the fixed charges rate were only 5.27 per cent (case c). In other words, a plant completely financed by the government should be able to produce power 30 to 40 per cent more cheaply than a plant that was industrially financed.

These calculations show that 'fixed charges' and 'profits' have a very considerable incidence on production cost.

[1] See article by A. Alexandrov in *Etudes Soviétiques*, December 1956, p. 61.

[2] Soviet cost estimates were discussed in an article by Harry Schwartz in *The New York Times* of 16 January 1955.

¶ *Is the U.S.S.R. assuming the lead in the industrial exploitation of nuclear power?*

On the information available to date, the Soviet Union would appear to be on the way to supremacy in the industrial utilization of nuclear power. By 1960 that country will, if its nuclear power programme is carried through, have nuclear power stations with a total capacity of between 2 and 2½ million kilowatts, as compared with a total of 1 million kilowatts in Britain and 700,000 kilowatts in the United States.

The Soviet Union, like the United States, is rich in the conventional sources of energy: coal, oil and waterpower. The Soviet Union is, however, in more urgent need of nuclear power than is the United States, because it is a country of great distances and less developed communications. Certain industrial regions in the Soviet Union are dependent on coal which has to be transported from mining areas many hundreds of miles away. This not only increases industrial working costs but is a heavy strain on the communications system. The seriousness of the transport problem will be realized when it is noted that the operating of one thermal power station of 300,000 kilowatts capacity requires 2,000 train-loads of coal a year. These inconveniences will disappear with the advent of nuclear power stations.

Apart, however, from its purely national needs, the Soviet Union is prompted by more general considerations to devote such great efforts and so vast an amount of capital to the industrial exploitation of nuclear energy. In seeking to intensify the peaceful utilization of the atom, the Soviet Union is actuated by three main motives:

(a) to show the world the importance attached to the industrial use of nuclear power as distinct from its exploitation for military purposes;

(b) to be in a position to assist countries professing the same ideology, most of which—and China in particular— are greatly in need of this new source of power;

(c) to be able to participate in the international atomic market, by supplying to other countries, and above all the underdeveloped countries, nuclear reactors and fissile material at competitive prices.

If to these motives be added the Marxist theory of the influence that technology can exercise on the economic and social structure, little further explanation is needed of the Soviet Union's intensive efforts to accelerate nuclear and thermonuclear development. We must, however, leave the question of the economic and social incidence of technology to a later chapter.

5. FRANCE'S NUCLEAR PROGRAMME

France at present comes fourth in the atomic hierarchy. She intends that the fulfilment of her nuclear development programmes shall establish her status as one of the world's great atomic powers.

In October 1945 the 'Commissariat à l'Energie Atomique' was set up, and in the meantime France has adopted two five-year programmes of atomic development for pacific purposes.[1]

The initial aim of French atomic policy was to train teams of research workers and engineers, and to place at their disposal laboratories, research equipment and essential raw materials. For the realization of this aim a 'Centre d'Etudes Nucléaires' was created at Saclay.

The first five-year programme of nuclear development, which was subsequently dovetailed into the 1955 programme, contemplated:

(a) the generation of electricity by nuclear power stations;
(b) the development of nuclear propulsion units, particularly for ships;
(c) the production of radioisotopes for use in medicine, agriculture and industry, as well as in many branches of scientific and technical research.

This first five-year programme contemplated the completion in 1957 of the following main projects:

[1] A detailed account of French atomic policy will be found in a special edition of the review *Science et Vie*, published under the title 'L'Energie atomique', in December 1956. In a preface to this special edition M. Francis Perrin, the 'Haut Commissaire à l'Energie Atomique', describes the main features of the French nuclear programme.

(a) construction of a 'Centre de Production de Plutonium' at Marcoule, comprising three large reactors (G.1, G.2 and G.3), and construction of an ancillary chemical extraction plant. (Of the three reactors, one will have a capacity of 5,000 kilowatts and the other two 30,000 kilowatts each);
(b) construction of a high flux reactor (E1.3) at Saclay for studying the resistance of reactor materials to the destructive action of radiation;
(c) construction of a large proton accelerator (also at Saclay) with a rated energy of 2,500 million electron volts.

In 1957 a start will be made with the execution of the second five-year programme, which provides in particular for:

(a) the creation at Grenoble of a new research centre, equipped with a powerful nuclear reactor;
(b) the construction of two experimental reactors at Chatillon;
(c) the construction at Chinon of the first nuclear power station of 'Electricité de France'.

France possesses sufficient uranium and thorium resources to satisfy all her nuclear fuel requirements. Present known resources of uranium in metropolitan France are put at 50,000–100,000 tons.[1] The output of the processing works at Le Bouchet, near Paris, will be sufficient for the nuclear fuel requirements of the reactors at Chatillon, Saclay and Marcoule.[2] A new factory for the treatment of thorium is being built; it will produce the nuclear fuel needed for future breeder reactors. The Marcoule plant will produce 100 kg. of plutonium a year when the three reactors (G.1, G.2 and G.3) are in service.

The question of the construction of nuclear plants for the

[1] According to a statement made by M. G. Quille, Minister of State, on 7 December 1956 (see *Industries Atomiques*, 1956, No. 3).

[2] It was anticipated that by 1957 the works would have a yearly output capacity of 380 tons of chemical concentrates (60%) of uranium, as well as 300 tons of crude uranium metal and 300 tons of nitrate of thorium, both of the requisite degree of purity for reactor use.

Total French production of uranium metal is expected to reach about 500 tons by 1958, 1,000 tons by 1961 and 3,000 tons by 1975.

production of electricity is now being studied. In this connexion the main responsibility will rest upon the 'Electricité de France', whose functions will be analogous to those of the Central Electricity Authority in Britain. It is anticipated that the first two nuclear power stations will be in operation within five years from now. Construction of the first of these two, at Chinon, with a capacity of 70,000 kilowatts, is planned to begin in 1957, and it is to come into operation in 1959. It should be noted, however, that by the end of the same year the three Marcoule reactors will already be generating 65,000 kilowatts of electricity.

France is in the fortunate position of having indigenous reserves of the raw materials of nuclear energy in sufficient quantity to enable her eventually to cover the whole of her industrial power requirements from this source. In spite, however, of her urgent need of this new form of energy, she is at present far behind Great Britain in the development of nuclear power production for industrial use. She is also in danger of being outdistanced in this respect by other countries, and in particular by Western Germany and Japan, who are taking energetic steps to catch up with the countries which entered the nuclear field before them. The relative slowness of France in this field is due to an insufficiency of financial resources. Only 0.98 per cent of French budgetary expenditure is devoted to development of nuclear power production.

6. OTHER COUNTRIES' NUCLEAR PROGRAMMES

Apart from the four 'atomic powers', other countries have embarked upon—or at least are preparing—programmes for the development of nuclear power production for peaceful purposes. We give below some details of the atomic policy of some of these countries:

Canada

Canada, which appears likely to become the world's largest producer of uranium, was among the first countries to engage in systematic nuclear research. Her first nuclear reactor, at

Chalk River, dates from 1945. The second, which is used for the production of plutonium and uranium, has been in operation since 1954. Two other research reactors are under construction at Chalk River. The first, which will be ready in 1957, is intended for the testing of reactor materials, and for the production of plutonium and isotopes. The second is a small reactor of the 'swimming pool' type.

Canada is to build four further reactors of different types. The first of these, now under construction at Ontario, will have a capacity installed of 20,000 kilowatts and will cost 15 million dollars. The second will supply power to the paper industry, the third will generate not only electricity, but also heat for direct heating purposes, while the fourth will be a normal nuclear power station producing electricity for the general needs of the country.

Western Germany

Western Germany is making her delayed entry into the atomic world and is strenuously endeavouring to make up for lost time. There can be little doubt that, with her formidable technical, industrial and scientific equipment and capabilities, her progress in the nuclear sphere will be rapid and impressive. One of Western Germany's first steps was to draw up plans for the co-ordination of research and for the training of scientific and technical personnel. 'Our primary preoccupation is the training of the necessary personnel,' said the West German Minister for Atomic Questions, Herr Strauss, in January 1956.

The Federal Republic's nuclear programme provides for the installation, in various parts of the country, of 10 reactors for study and research purposes. Five of these will come from the United States, two from Great Britain and the remaining three will be constructed in Germany. It is understood that plans are well advanced for the construction of nuclear power stations. In February 1957 it was decided to construct three such stations, each with an installed capacity of 100,000 kilowatts. All three are to be in operation by 1965. It may be noted, finally, that the Germans are showing particular interest in nuclear propulsion for ships and aircraft.

Japan

Japan, which is also intent on becoming an 'atomic power', and possesses the pre-requisites for rapid nuclear development, has drawn up a programme which, as a first phase, contemplates the construction of five reactors. Two of these are intended for research on nuclear propulsion for ships. The other three, with a capacity of between 20,000 and 65,000 kilowatts each, will produce electricity for industrial and general use. A first reactor, supplied by the United States, is already in course of erection and should come into operation in 1957. In a recent interview with *The Financial Times*, the Chairman of the Japanese Atomic Energy Commission, Koichi Uda, said that of the 8.4 million kilowatt capacity (hydro and thermal) to be developed over the next four years, 3 million kilowatts would depend on imported fuel. It was this 3 million kilowatts, he said, that should ultimately be produced from nuclear reaction to save import costs.[1]

Japan, who leads the world in the construction of supertankers, and comes second to Britain in that of tankers of normal tonnage, is at present preparing plans for a 40,000-ton tanker powered by a 20,000 h.p. nuclear reactor.

India

An underdeveloped country like India has a particularly urgent need for nuclear power, and for this reason she is directing her efforts in the nuclear field exclusively to the peaceful use of the atom. Her first research reactor, at Trombay, near to Bombay, was put into operation on 20 January 1957. In inaugurating this reactor, the Prime Minister of India, Mr. Nehru, emphasized that India would never use atomic energy for 'an evil purpose'.[2] This reactor is of the 'swimming pool' type and cost $6 million; it will be used for nuclear research purposes and for the training of personnel. A second and larger research reactor is now under construction.

In addition to research reactors, however, India is contemplating the construction of nuclear power stations. The first of

[1] *The Financial Times*, 19 February 1957.
[2] *The New York Times*, 21 January 1957.

these will be at Ahmedabad and will have a capacity installed of between 60,000 and 100,000 kilowatts.

India's nuclear programme also provides for the erection of a heavy water plant and a fertilizer factory, at a cost of £15 million. (Apparently the production of heavy water is less costly if it can be combined with the manufacture of fertilizers.)

As nuclear power is (to quote Dr. H. I. Bhabha, Chairman of India's Atomic Energy Commission) a 'necessity' for India, we may expect that great efforts will be made to amplify and speed up the Indian nuclear power programme in the next few years.

China

China also has an urgent need for this new source of power, particularly in view of the vital importance of the power factor for the success of her present efforts to industrialize her economy. The Soviet Union has undertaken to afford China scientific and technical assistance and to supply her with research reactors and cyclotrons, as well as radioisotopes and other nuclear materials. It is believed that China is preparing a long-term programme for the construction of high-capacity nuclear power stations.

Other countries

Programmes for the industrial exploitation of atomic energy are being prepared in other countries also. *Italy*, which does not as yet possess a reactor, is studying plans for:

(a) the construction of 3 to 5 research reactors, of which the first, with a capacity of 1,000–5,000 kilowatts, will be bought from the United States and installed in 1958 near to Milan;
(b) the construction of three nuclear power stations, each with a capacity of 100,000 kilowatts; and
(c) the provision of a reactor to assist research on nuclear propulsion.

Belgium already has one research reactor and is proposing to buy two or three others from the United States. One of these

reactors is to be shown at the Universal Exhibition in Brussels in 1958. Two nuclear power stations are in contemplation, one (with a capacity of 75,000–100,000 kilowatts) for Belgium and the other for the Belgian Congo.

Norway has had a heavy-water reactor (at Kjeller) since 1951. A new reactor, of the breeder type, is now under construction and a second is planned for use in research on nuclear propulsion for ships. According to press reports of January 1957, the Norwegian naval shipyards will collaborate in the construction of an atomic super-tanker of 80,000–100,000 tons, the cost of which is estimated at about 100 million kroner.

Sweden is fairly advanced in nuclear matters. In addition to the research reactor at present in use in Stockholm, it is proposed to construct:

(a) 3-5 other research reactors;
(b) two reactors to produce heat for space-heating;
(c) three nuclear power stations with a capacity of 75,000, 100,000 and 300,000 kilowatts, respectively; and
(d) a reactor at Göteborg for research on nuclear propulsion for ships.

Holland is at present building two research reactors and is considering the construction of a small experimental nuclear power plant of the type known as S.U.S.P.O.P.

Switzerland has begun the construction at Würlingen of an experimental reactor, the cost of which is estimated at 25 million Swiss francs. She also has a small reactor, of the 'swimming pool' type, which was a gift from the United States on the occasion of the Geneva atomic conference.

Eastern Germany announced in January 1957 that work had been started on that country's first nuclear power station. It will have a capacity of 70,000 kilowatts. A reactor and a cyclotron will be brought into service during 1957. It may also be mentioned that there are important deposits of uranium in two areas, one of which is in the Erzgebirge (Saxony) and the other near to Gera (Thuringia). The daily output of the latter area is said to be about 2,000 tons of good quality ore.[1]

[1] Fr. Gérard: 'Découverte récente de gisements d'uranium dans les républiques populaires de l'Europe,' published in *Industries Atomiques*, December 1956.

Poland expects to have works in operation in the very near future for the processing of the uranium which at present is exported to the Soviet Union. She is also contemplating the construction of a nuclear power station. A Nuclear Research Institute is being built at Cracow and will be equipped with apparatus supplied by the Soviet Union.

Czechoslovakia is in the first rank of the uranium-producing countries of Eastern Europe. The most important deposits are those at Joachimstal. An agreement has been concluded under which the Soviet Union undertakes to supply Czechoslovakia with scientific and technical documentation and has already begun the construction in Czechoslovakia of a 2,000 kilowatt reactor and a powerful elementary particles accelerator. (The Soviet Union is rendering similar aid to *Bulgaria*, *Rumania* and *Hungary*.)

In addition, Czechoslovakia is preparing plans for the construction of nuclear plants for the production of electric power. A start has been made with the erection of the first of these plants in the Hlon valley. It will have a capacity of 150,000 kilowatts and will come into service in 1960. A second is to be completed by 1962. Subsequently, other stations will be built in Moravia and Slovakia.

7. INTERNATIONAL CO-OPERATION IN ATOMIC DEVELOPMENT

International co-operation is a fundamental pre-condition for optimum development of atomic power to serve peaceful purposes. Only the unrestricted exchange of views and ideas between scientists of different countries and the sharing of information on the results of research and experimentation can ensure the maximum development of nuclear science and technique. The atomic conference at Geneva was, as we have seen, the first manifestation on a world scale of such a spirit of co-operation, and has greatly contributed to the progress that has since been achieved in the nuclear sphere.

Although there are gaps in the various existing forms of co-operation, and that co-operation falls short of what the peoples of the world had been hoping for, definite steps have none the

less been taken in the right direction and we can only hope that before long international collaboration will become general, sincere, and unhampered by fear or mistrust.

Atomic co-operation is at present based mainly on bilateral agreements, and on various organizations that have already been created or are in course of formation. The only atomic organization on a world scale is the International Atomic Energy Agency, a specialized agency of the United Nations, constituted in October 1956. Here are some of the features of these different instruments of co-operation:

¶ *Bilateral agreements*

At the Geneva atomic conference the large atomic countries expressed their readiness to afford other countries scientific and technical assistance. Under agreements already concluded with some thirty countries, the United States will facilitate nuclear research in those countries by supplying the necessary nuclear fuel. The quantity of fuel to be provided is in principle 6 kilograms of uranium 235 enriched to 20 per cent. In certain cases, however, the amount may be increased; thus, in the agreement with France it has been fixed at 40 kilograms. To cover these allocations of nuclear fuel for research purposes, the United States has earmarked 20,000 kilograms of enriched uranium.

Great Britain also has concluded a series of agreements with other countries, providing for the exchange of information and materials as well as for close collaboration on a whole range of questions connected with the use of atomic energy for peaceful purposes.

Similarly, the Soviet Union has entered into agreements with other communist countries and with certain non-communist countries. Under its agreement with Egypt, the Soviet Union will afford 'scientific and technical aid in the construction of a nuclear physics laboratory at Cairo, and will collaborate in the development of the pacific utilization of atomic energy in Egypt'.

Apart from the bilateral agreement arrangements, there are various organizations whose object it is to assist atomic

development, particularly in the spheres of research, training, exchange of information, and the application of atomic energy to industrial and other peaceful uses. The following are the more important of these organizations:

I. *European Organization for Nuclear Research* (*C.E.R.N.*)

The object of this organization, which has its headquarters in Geneva, is to study the structure of the atomic nucleus, the nature of protons and neutrons and the behaviour of mesons. The C.E.R.N. laboratory will be equipped with two accelerators:

a 600 million electron volt synchro-cyclotron;
a 25,000 million electron volt proton synchroton.

The first of these two machines, which will be ready in two or three years, will be more or less comparable with the Soviet synchro-cyclotron—at present the largest in the world—which accelerates protons up to an energy level of 680 million electron volts and makes it possible to obtain neutron groups with an energy of 600 million electron volts.

The second machine, the proton synchroton, will be the most powerful yet built, the Berkeley bevatron having a limit of only 6,000 million electron volts. This apparatus, which will be ready for use in six or seven years, will permit of the acceleration of the speed of nuclear particles up to 250,000 kilowatts per second, or approaching the speed of light.

It is the intention that this European laboratory shall be a centre for international scientific collaboration and a medium for the dissemination of information essential to the progress of nuclear science.

In this organization, which was founded in 1953, the following twelve countries at present participate: Belgium, Denmark, France, Great Britain, Greece, Holland, Italy, Norway, Sweden, Switzerland, Western Germany and Yugoslavia.

II. *European Atomic Energy Society*

This organization was formed—also in 1953—by the following eight countries: Belgium, France, Great Britain, Holland, Italy, Norway, Sweden and Switzerland. Its main objects are to encourage research on safety precautions; to bring about the

standardization of atomic terminology and of the symbols used in nuclear science; and to facilitate the diffusion of nuclear knowledge by organizing periodical conferences of nuclear scientists and technicians.

III. *O.E.E.C. Steering Committee for Nuclear Energy*

A special committee of the Organization for European Economic Co-operation, Paris, has been set up to study and make recommendations with regard to the following questions:

(a) Security measures and liberalization of trade in nuclear materials and equipment;
(b) creation of joint undertakings for isotope separation, chemical separation of plutonium, construction of prototype reactors and, possibly, production of heavy water.

IV. *Euratom*

In June 1955 a conference of representatives of the six nations of the European Coal and Steel Community (E.C.S.C.) was held at Messina. These representatives decided to put forward to their respective governments two proposals:

(1) for the creation of a European Common Market, open to all countries desirous of participating;
(2) for the formation of a supra-national European atomic agency (Euratom), whose main function it would be to promote the peaceful development of atomic energy and thereby contribute to the development of industry and economic activity in general.

It is contemplated that Euratom should comprise:

a Council of Ministers;
a European Atomic Commission;
a Court of Justice;
a Common Assembly.

Euratom is to provide a medium for the pooling of nuclear knowledge within the community, and is to have a common research centre equipped with experimental reactors. It will guide the investment activities of individual nuclear enterprises in the various countries, and will construct—or participate in the construction of—common nuclear power installations of a

capacity that would be beyond the means of individual enterprises or countries. It is proposed that Euratom should have practically complete monopoly rights over all radioactive materials, natural nuclear fuels and prepared fissile material, whether produced within or imported into the area; and that it should have complete control over the allocation of supplies of nuclear fuel to users.

Euratom's 'three wise men' visited Washington in February 1957. On their return their leader, M. Louis Armand, was able to report that the American authorities had promised full co-operation in the realization of Euratom's plan to produce 15 million kilowatts of nuclear power capacity by 1967.[1]

V. *Joint Institute for Nuclear Research (Eastern countries)*

Created in March 1956 on the initiative of the Soviet Union, this institute serves 12 countries of Eastern Europe and Asia (Albania, Bulgaria, Czechoslovakia, Hungary, Poland, Rumania, Soviet Union, Ukraine, Byelorussia, China, Outer Mongolia and North Korea). The institute is at Kalinin (U.S.S.R.). Its object is to promote collaboration among scientists of the member countries in the realm of nuclear research and experiment, and to extend the possibilities of using atomic energy for peaceful purposes. The institute will accept as members countries other than those mentioned above.

The Soviet government has transferred to the Joint Institute for Nuclear Research the Institute for Nuclear Problems, of the Soviet Union's Academy of Science, with its 680 million electron volt synchro-cyclotron, and its electro-physical laboratory which is to have a 10,000 million electron volt proton synchro-phasotron. In addition, the Joint Institute is to be furnished with laboratories for theoretical physics and neutron physics, as well as with an ion accelerator and other experimental apparatus.

VI. *International Atomic Energy Agency*

The establishment of the International Atomic Energy Agency,

[1]On 8 May 1957 the press published details of a report submitted by the "Three Wise Men" Committee to the governments of the six Euratom countries. The report proposes a ten-year programme of nuclear development which, at a cost of $5,250 million (£1,875 million) would, by 1967, provide the Euratom community with a nuclear power production capacity of 15 million kilowatts.

first proposed on 8 December 1953 by President Eisenhower, was decided upon by a unanimous vote of the General Assembly of the United Nations on 4 December 1954, and the Agency's statute was approved on 23 October 1956.

The main object of the Agency, as defined in the statute, is 'To encourage and assist research on and the development and practical application of atomic energy for peaceful uses throughout the world . . . (and) to establish and administer safeguards designed to ensure that special fissionable and other materials, services, equipment, facilities and information made available by the Agency should not be used in such a way as to further any military purpose.'

Member states will place fissionable (*anglice* fissile) material at the disposal of the Agency for allocation to those members who need and apply for such material. The United States has already set aside 5,000 kg. of uranium 235 for the Agency. There is to be a Council of Governors composed of representatives of:

(a) the countries which are most advanced in atomic technique;
(b) countries which produce nuclear raw materials;
(c) countries in various regions of the world which do not come under heading (a) or (b); and, finally,
(d) countries designated by the General Assembly of member states.

Decisions are taken by the Council on a simple majority vote. The Council appoints the Administrative Director and is responsible for the appointment and control of personnel. The headquarters of the Agency is in Vienna.

The various institutions, whose essential characteristics are outlined above, all have as their objective the promotion of the peaceful use of atomic energy. The reader may be somewhat surprised at their multiplicity, the dispersion of efforts which all have the same objective, and the absence of effective co-ordination. We shall return to this subject in Chapter 10.

Chapter 6

WILL ATOMIC ENERGY SUPERSEDE THE CONVENTIONAL SOURCES OF ELECTRIC POWER?

1. THE EFFECT OF TECHNICAL PROGRESS ON POWER PRODUCTION COSTS

From what has been said in the preceding chapter it is clear that the industrial use of atomic energy is not a future possibility but a present-day reality. Electricity will be produced in nuclear power stations not only in ever-growing quantity but at a cost lower than that of electricity from the traditional sources.[1]

¶ *Atomic energy now an established economic factor*

At its present cost of 0.6d. (10 mills) per kilowatt-hour, nuclear power is already competitive with the conventional types of power for use in industry. The nuclear programmes which we have briefly outlined above, or the extensions of existing programmes that are constantly being announced, indicate the degree to which various countries are contemplating the development of the industrial use of atomic energy.

Thus, under the first revision of Great Britain's original nuclear power programme that country will by 1960 possess nuclear power stations with an aggregate capacity installed of a

[1] The experts appear to be agreed on this point—except perhaps for a few dissentients in the United States. Mr. Corbin Allardice, acting as leader of the Panel Discussion on Atomic Energy, organized in September 1956 by the International Bank for Reconstruction and Development, made the following remark:

'There seems to be general agreement that the fuel cost component of electric power from atomic energy sources will be less than the comparable cost components from coal, oil, or gas, except in low-cost areas, such as the United States.'

million kilowatts, producing electricity at a cost less than that of power from thermal stations. By 1965 the output of nuclear power stations will cover at least a quarter, and by 1975 seven-tenths, if not the whole, of Great Britain's total power requirements. By 1960 the Soviet Union will have built nuclear power stations with a total capacity of from 2 to 2½ million kilowatts and will obviously go on extending this capacity thereafter. The United States will have attained an overall capacity of 700,000–1,000,000 kilowatts by 1960 and of 3-4 million kilowatts by 1965. It is expected that by 1975 the total capacity will have risen to 50–75 million kilowatts. The six Euratom countries contemplate the construction, by 1967, of stations capable of producing 15 million kilowatts of nuclear power.

It must further be remembered that the cost of producing a kilowatt-hour of nuclear power is a factor whose importance varies according to the stage of economic development reached by each country and the extent of its indigenous sources of energy. Before embarking on a nuclear power production programme, each country must first examine the production cost of the power which it is already deriving from conventional sources. If at the present stage of development of nuclear technique, nuclear power is already competitive in the industrialized countries, it is easy to appreciate the inestimable value that such power will represent for underdeveloped countries in which either electricity is scarce or completely lacking, or the cost of producing it is excessively high.

Not only is nuclear power already competitive with conventional power in certain countries, but it is certain that its cost will progressively diminish as nuclear technique improves, while on the other hand the cost of power from the traditional sources will increase.

There are a number of factors which will contribute to a progressive reduction in the cost of nuclear power. Some of these factors are technical and scientific in character, others political.

The technical and scientific factors, which we will now consider, are related to the advances that are to be anticipated in two fields: that of pure research, and that of research concerning the industrial applications of nuclear power.

The four main objectives of current research and experimentation are the following:

(a) the perfecting of the breeder reactor;
(b) the direct conversion of nuclear radiation into electricity;
(c) protection against the dangers of radioactivity;
(d) the achievement of controlled thermonuclear fusion.

¶ *Importance of the breeding process*

In a previous chapter we briefly explained the nature of the 'breeder' reactor process, the principal object of which is to produce more nuclear fuel than the reactor consumes. Once this process has been perfected and can be adopted on a large scale, it will become possible to satisfy the world's total power requirements by the use of a quite insignificant quantity of new fissile material.

Whereas a few years ago it was calculated that 1 ton of uranium could be made to produce, by the nuclear fission process, as much heat as was obtainable from 10,000 tons of coal, Sir John Cockcroft stated, in the Panel Discussion organized by the World Bank in September 1956, that the progress that had been achieved to date in breeder research and experimentation, suggested that it should be possible, by the use of the breeder reactor, to raise this equivalence to 1 ton of uranium = 50,000–100,000 tons of coal. Obviously such a development would greatly reduce the cost of producing nuclear power. In the light of Sir John's remarks, it would seem that, thanks to the breeding process, it may be possible within the next few years to reduce that cost to 0.2–0.3d. per kilowatt-hour, as compared with the estimated cost of 0.6d. for the output of the first nuclear power stations.

Generalization of the use of breeder reactors will thus result in a gradual fall in the cost of producing nuclear power. In this context it should not be forgotten that only 1/140th part of natural uranium is fissile matter, and that the calorific equivalence realizable in the first nuclear power stations will be approximately 10,000 tons of coal = 1 ton of uranium, whereas the

theoretical atomic equivalence is 3,000,000 tons of coal = 1 ton of uranium.[1]

It is to be hoped therefore that technical progress will soon make it possible to equip future nuclear power stations with breeder reactors. This is not contemplated in the case of the stations now under construction in Great Britain and the United States, for two reasons:

(a) the great amount of experience that has been acquired with the simpler non-breeder reactors;[2]
(b) the fact that breeder reactors require a very considerable and expensive initial charge of fissile material, which is not the case with other types of reactor.[3]

However, once atomic competition begins in the world market, the competing nations will be obliged to adopt the breeder process, which is obviously destined to be the process of the future.

¶ *Direct conversion of nuclear radiation into electricity*

If the efforts at present being made to find a way of producing electric power from nuclear energy direct—that is to say, eliminating the intermediate stage in which the energy is converted into heat for the generation of steam—are successful, the incidence of this development on the cost of nuclear power production will be very considerable. According to the McKinney report, the heat exchangers and other apparatus now necessary for the conversion into electricity of the energy produced in a reactor account for one half, or more, of the

[1] The following energy equivalents are often quoted:
1,000 kilowatt-hours are obtainable by the complete combustion of 125 kg. of coal, or 400 kg. of lignite, or 83.3 kg. of petroleum; or by the complete fission of 0.04 gram of uranium 235.

[2] Referring to the United Kingdom's first nuclear power station, Sir Christopher Hinton expressed the opinion that it was preferable to concentrate on the use of reactor types that had already proved themselves, rather than to encourage the construction of too great a variety of 'improved' types that had still to do so.

[3] In the discussion at the Geneva Atomic conference on the subject of nuclear fuels, there was some divergence of views among the experts from Canada, the United Kingdom and the United States as to the best methods of using uranium, plutonium and thorium. According to the Australian representative, Professor M. Oliphant, this divergence was due to the different situation existing in the respective countries with regard to the fuels in question.

total capital cost of nuclear power station construction. Further, only 25 per cent of the energy released by the fission process passes in the form of electricity into the national grid.

The direct conversion of nuclear energy into electricity would, however, mean not only a great saving in capital costs, but would improve the ratio of electricity produced to energy released. The progress already made in research in this sphere would appear to indicate the feasibility of this method of power production. Addressing an international congress of producers and distributors of electric current, held in London in September 1955, Lord Citrine, Chairman of the British Central Electricity Authority, said that one could foresee the direct generation of electricity from atomic energy without the intermediate stage of conversion of the energy into heat for the production of steam. In an article published in February of the same year, Professor Petrovsky of the Soviet Union asserted that it would eventually be possible to derive electricity directly from the nuclear reactor, instead of having to generate steam to drive turbo-electric alternators.

According to the American McKinney report, the direct conversion of radiation into electric energy has already been accomplished on an extremely small scale and at very low efficiencies, and is already proving useful in limited and highly technical applications. The same report remarks that 'it is at least conceivable that some one of the approaches to controlled thermonuclear power may lend itself to direct conversion of the energy of radiation to electric energy.'

¶ *Protection against danger from radioactivity*

Protection against the radioactivity hazard is a problem which affects both the cost of producing nuclear power and the possibilities of using it for other than purely industrial purposes, and in particular for the propulsion of means of transport.

When the utilization of atomic energy begins to develop on a large scale, and the number of nuclear reactors in operation multiplies accordingly, it is essential that there shall be adequate protection against these hazards, not only for personnel directly engaged in the production or use of nuclear power or other

nuclear products, but also for the general public. This problem is one on which some misgivings have been felt by the layman, partly because the experts concerned with genetics—the science of heredity—have frankly admitted they still know very little about the effects which atomic rays may have on the human species. Professor W. V. Mayneord, of the Medical Research Council of Great Britain, when presiding over the session of the Geneva conference at which the problem of radiation hazards was discussed, said that 'humanity's greatest adventure' (as he described the peaceful development of atomic energy) must, like all adventures, involve risk; but, he added, it is a 'calculated risk'.

Various countries have adopted safety standards to reduce this risk to a minimum. Although it is estimated that in undergoing a complete radiological examination a person absorbs something between 1 and 10 roentgens of radiation, the International Commission on Radiological Protection (western nations) has fixed the exposure tolerance at 0.3 roentgen per week, a dosage which the human body can absorb indefinitely without danger. The Russians have established the maximum permissible dosage at 0.05 roentgen per day, i.e. 0.35 roentgen per week.

In order to afford the necessary degree of protection against harmful radiation, nuclear reactors have to be surrounded by very thick shielding walls, a requirement which adds appreciably to the production cost of the nuclear kilowatt-hour. In their report on experience of the operation of the first nuclear power station, the Soviet experts at the Geneva conference stated that one of the reasons for the relatively high cost of the nuclear power produced was the cost of the safety precautions, and that those precautions had in fact proved to have been somewhat exaggerated.

In its semi-annual report of 30 January 1957 the American Atomic Energy Commission announced that the progress achieved in the past thirteen years in the matter of protection against radioactivity was 'without precedent in industrial history'. This is part of the explanation why in a number of countries programmes have been drawn up for the use of

nuclear power for marine propulsion, a possibility which only a few years ago was regarded as inconceivable.

Further, the recuperation of radioactive fission products which can be put to profitable use will in the near future result in a reduction in the cost of the nuclear kilowatt-hour. In a paper presented at the Geneva conference by E. Glueckauf, of the Atomic Energy Research Establishment, Harwell, it was estimated that, with an annual consumption of 20 tons of nuclear fuel, not only could as much electricity be produced as can be derived from 60 million tons of coal, but the following valuable elements, among others, could be obtained as by-products:

ruthenium	to the approximate value of	£288,000
rhodium	,, ,, ,,	£220,000
palladium	,, ,, ,,	£17,000
xenon	,, ,, ,,	£780,000

The value of these by-products would appreciably affect the cost of nuclear power production. An even greater credit factor is the commercial value of the radioactive isotopes which are produced in reactors. One of the American delegates at Geneva, Dr. P. C. Aebersold, said that at a rough estimate the use of isotopes meant an economy of one thousand million dollars a year for world industry. The Chairman of the session at which this statement was made, J. V. Kurdiumov of the Soviet Union, remarked, however, that savings to industry from the use of isotopes were difficult to estimate in terms of money, since isotopes made possible new production techniques that had previously been impossible. A similar remark might be made about the value of radioisotopes to agriculture. According to W. R. Singleton of the Brookhaven National Laboratory (U.S.A.), radioisotopes are rendering immense service in the fight against plant diseases which cause a loss of three thousand million dollars a year to American agriculture.

¶ *Controlled thermonuclear fusion: a production cost that tends towards zero*

As we have already said, there seems every prospect that within only a few years control of thermonuclear fusion will have been

accomplished. Progress in this direction in the United States, the Soviet Union and Great Britain justifies the belief that we are on the eve of the most revolutionary scientific achievement the world has yet witnessed.

Soviet scientists have already announced that they have succeeded in controlling thermonuclear fusion on a laboratory scale. The British scientists are also believed to be making good progress in this field.[1] As regards the United States, the following highly significant remark was recently made by Senator Clinton Anderson:[2]

'I think there's going to be very little secrecy on the industrial uses of hydrogen power after another year or so.'

Altogether, there seems little doubt that we are rapidly nearing the moment when the harnessing of thermonuclear power for industrial use will be an accomplished fact.

As we have already suggested, this development will mean that the cost of power will tend to fall to zero. The raw material —hydrogen—is as abundant as the water in the oceans; the plant required for the fusion process will be much less costly than that used for uranium fission; the energy released will be converted directly, and without loss, into electricity; the danger from radioactivity will be practically eliminated; and the possible industrial applications of the power produced will be innumerable. The advent of controlled thermonuclear fusion will mark the opening of a new phase of the industrial revolution.

2. LOWERING THE COST OF NUCLEAR POWER BY BANNING NUCLEAR WEAPONS

While technological improvements are progressively reducing the cost of producing nuclear power and may, when controlled thermonuclear fusion has been achieved, eventually bring it down to zero, there is one measure in the field of international policy which would immediately result in a very great reduction

[1] See article by William L. Laurence ('Progress on Harnessing Hydrogen Power') in *The New York Times* (International Edn.) of 27 January 1957. See also an article ('Harwell Looks Ahead') in *The Financial Times* of 2 March 1957, which states that 'Britain is now working along a direct line of research and development that U.K. scientists are convinced will, within the foreseeable future, lead to harnessing the immense power of hydrogen fusion, at least on an experimental scale.'

[2] *U.S. News & World Report,* 11 January 1957, p. 125.

in the present price of electricity produced by nuclear fission. The price of the nuclear raw materials, uranium and thorium, is at present very high.[1] This is largely due to the heavy demand for these materials for use in the manufacture of atomic weapons. It is certain that almost the whole of the uranium metal (estimated at about 25,000 tons) produced in the Western world in 1957 will be absorbed by military requirements.[2]

If it were possible to arrive at an international agreement for the banning of atomic weapons, the price of the raw material would fall very considerably, for the following reasons:

(a) The quantities of fissile material required for industrial purposes are limited, even apart from the possibilities opened up by the 'atomic self-reproduction' or 'breeder' process. In a paper presented at the Geneva atomic conference, Mr. E. Glueckauf, of the Atomic Energy Research Establishment at Harwell, stated that the British Atomic Energy Programme envisaged in the foreseeable future the possibility of saving 60 million tons of coal a year by burning approximately 20 tons of nuclear fuel to produce electric power. The Swiss engineer, A. Winiger, has calculated that, in order to satisfy

[1] There is some divergency in the data relating to the prices of the raw materials. The first prices announced by the American Atomic Energy Commission, on the occasion of the Geneva atomic conference (see Conference Document P/398), were $40 per kg. of natural uranium, and $25 per gr. of uranium enriched to 20% with the fissile isotope uranium 235, making $25,000 per kg.

The basic price paid in July 1956 by the Eldorado Mining and Refining Ltd., a government company which processes uranium ore on behalf of the Canadian Atomic Energy Commission, was $7.25 per pound for the uranium concentrate U.308. Previously the price had been $10-11 per pound.

The guaranteed minimum price announced by the American Atomic Energy Commission for the period 1962-7 is $8 per pound of the oxide U_3O_8, for the rich chemical concentrates, plus (in the case of factories not amortized) an amortization premium for a minimum period of five years.

[2] According to a statement issued by the American Atomic Energy Commission, the output of uranium ore in the United States totalled 3 million tons in 1956, and within a few years should reach 6 million tons. On the basis of the assumed uranium content of the ore, it is calculated that an output of 3 million tons of ore should yield over 8,000 tons of uranium metal per annum, representing a value of at least $200 million. Canada is producing about 12,000 tons of uranium metal per annum, the value of which may be put at about $300 million. New uranium mills are being built with the aim of doubling, within a few years, the present processing capacity, which is at least 40,000 tons of ore per day. According to a statement by the Pitfield Company Ltd., 'Canada will by 1958 be producing about 40% of the free world's total uranium supply'. This statement would suggest that the production of uranium metal in the western countries amounts to at least 25,000 tons per annum.

his country's yearly requirements, her modern thermal power stations have to burn 4.4 million tons of coal, whereas the same amount of power could be generated in nuclear power stations from only 2 tons of uranium 235. It has further been estimated that the use of 1,000 tons of nuclear fuel per annum for the production of nuclear power would suffice to raise the per capita electricity consumption of the whole population of the globe to the present level of per capita consumption in the United States (and that without taking any account of power derived from other sources).

Even at the present stage of nuclear technique, and on the assumption that it will be possible to derive from 1 ton of uranium heat equivalent to at least 50,000 tons of coal (it will be remembered that the theoretical calorific equivalence is 1 ton of uranium = 3,000,000 tons of coal), the nuclear power stations in operation in 1965 throughout the world will not need more than 2,000–4,000 tons of uranium metal. It may here be noted that the submarine *Nautilus* is said to have sailed a distance of 50,000 miles on power generated from a quantity of uranium the size of an electric light bulb.

(b) While it is true that the present excessively high price of uranium is largely due to the cost of its extraction and processing, it is also true that, because of the great demand, the price is in the last resort determined by the price of the ore which is poorest in uranium. There are deposits of ore in many parts of the world, but its value depends on its uranium content. The richest ore so far discovered is that produced from the uranium mine at Shinkolobwe in the Belgian Congo. The ore deposits in the United States have an average content. Canada is at present the world's largest producer of uranium, and its ore deposits have a high uranium content.

If the manufacture of atom bombs and other atomic weapons were stopped, the resultant greatly reduced demand for uranium could be met by the use of richer ores whose processing is less costly. If, moreover, it were decided to 'denature' all the atomic bombs at present lying in the stockpiles held by the great powers, the fissile material thus recovered would, if made available for industrial use, suffice to cover the energy

requirements of the whole world for many years to come.[1]

The banning of the manufacture of atomic bombs is thus essential not only on humanitarian grounds, but also for purely economic and social reasons. If we wish to see the atom placed at the service of mankind, we must (to repeat President Eisenhower's phrase) 'strip its military casing'. This, however, pre-supposes an international understanding.

3. THE GREAT PROMISES OF NUCLEAR SCIENCE

What fantastic progress has been made in nuclear science since the day in 1942 when Enrico Fermi produced a few watts of heat in the world's first successful nuclear fission experiment! At that time scientists thought it might take 30, or even 50, years to reach the stage at which nuclear power could be produced in usable quantity. Speaking on 16 May 1946 before the George Washington House Forum, J. Robert Oppenheimer, the 'father' of the first atomic bomb, said:[2]

'If men are ever to speak of the benefits of atomic energy, I think these applications will at most play a very small part in what they have in mind. . . . No one knows to what extent such power will be economically profitable; no one knows to what extent technical problems may delay or complicate the development of atomic power as power.'

Today the large-scale production of nuclear power is not only possible but economically profitable.

¶ *Forecasts outdated by the rapid progress of nuclear science*

Science is advancing today at a pace hitherto unimaginable. Only two years ago scientists present at the Geneva atomic conference expressed the opinion that nuclear propulsion lay in the distant future. Today a number of countries are building or designing nuclear-powered ships, and the construction of super-tankers with nuclear engines is already an economic proposition. When the president of the Geneva conference, Dr. H. Bhabha, predicted that controlled thermonuclear fusion would

[1] It was estimated in February 1956 that a total of some 45,000 atomic bombs were then lying in the stockpiles of the United States, the Soviet Union and Great Britain.

[2] *The Open Mind*, by J. Robert Oppenheimer.

have been achieved within 20 years, a number of scientists thought him over-optimistic. Today we should not be unduly surprised to read in the morning newspaper that controlled thermonuclear fusion was a *fait accompli*.

The rapid progress of science is causing even the more optimistic of scientists to be cautious in their forecasts. In the Panel Discussion on Atomic Energy to which we have already referred, Sir John Cockcroft concluded his address with the following remark:[1]

'I am very conscious that in making this report most of what I have said will be overtaken by events during the next five years. It is certain, with the great power of creative technology today, that development will be rapid and capital costs of nuclear power projects will fall rapidly.'

Taking part in the same Panel Discussion, Admiral Strauss, Chairman of the American Atomic Energy Commission, while admitting 'how hazardous it is to predict the rate of progress,' added:[2]

'It is well to bear in mind that the store of technological knowledge is being expanded so rapidly and we are engaged in research and development on so many different reactor concepts, that a major break-through, putting us at or near the goal of economic nuclear power, could come with some suddenness.'

In summing up the discussions which took place at this gathering of some of the most eminent figures in the world of nuclear science, Mr. Corbin Allardice said:[3]

'In conclusion, I would stress a point made clear by all of our speakers. Progress of technological development in the atomic field is rapid. What has been said here today probably will be overtaken by events in the next five years.'

The facts of the nuclear situation would appear fully to justify the prudent predictions of these men of science, and it seems permissible for the rest of us to be very optimistic as to the rapidity with which the immense potentialities of atomic

[1] I.B.R.D. Informal Panel Discussion on Atomic Energy in Economic Development, 27 September 1956, p. 13.

[2] Op. cit., p. 15.

[3] Op. cit., p. 30.

energy will become available for the service of humanity.

¶ *New scientific horizons*

To give an idea of the present development of scientific knowledge it will suffice to mention a few recent announcements:

I. In January 1957 the Department of Physics of Columbia University, in a report submitted at a meeting of physicists presided over by Dr. I. I. Rabi, Columbia's Nobel Prize-winning physicist, announced that a concept of nuclear physics which had been accepted as fundamental for thirty years had been shown by very recent experiments to be erroneous.[1] The experiments had been suggested by two theoretical physicists, Dr. Tsung Dao Lee of Columbia University and Dr. Chen Ning Yang of the Institute for Advanced Study at Princeton, who had raised doubts as to the validity of this concept. The concept in question is that known as the 'principle of conservation of parity', and it has hitherto been as sovereign in nuclear physics as is the principle of the conservation of energy in general physics.

II. At the annual meeting of the American Physical Society, held in New York in January 1957, two nuclear scientists, Dr. Tihiro Ohkawa of the University of Tokyo and Dr. Lawrence Jones of the Midwestern Universities Research Association, described the design for a revolutionary type of atomic machine which would accelerate atomic particles to the enormous energy of 30,000 million electron volts, a performance of which no present-day accelerator is capable.[2] The bevatron at the University of California accelerates protons to energies of 6,000 million electron volts. In 1956 the Soviet Union's synchrophasotron was brought into use. This machine will accelerate atomic particles to energies of 10,000 million electron volts. It is believed that this accelerator can impart to the nuclei of the hydrogen atom a speed approaching that of light.

These giant machines will help the scientists to solve highly complex theoretical problems which are of capital importance

[1] The full text of this report was published in *The New York Times* of 16 January 1957.

[2] See article by William L. Laurence, 'Atomic Accelerator of a New Design', in *The New York Times* (International Edn.) of 3 February 1957.

for the development of the use of atomic energy for industrial and other peaceful purposes.

III. In December 1956 a team of twelve scientists, headed by Dr. Luis W. Alvarez, who had been working at the Berkeley laboratory of the University of California, announced the discovery of a way of producing atomic energy by a reaction which does not involve the use of uranium or require 'million-degree heat', as in the fusion reaction. This new process, which has been given the name of 'catalyzed nuclear reaction', was described as 'thus far little more than a laboratory curiosity'. It may, however, said Dr. Alvarez, point a way towards taming the intense heat of the hydrogen bomb to make it useful for peaceful purposes. In this process an atomic particle, known as a negative mu-meson, is used as a catalyst to cause an ordinary hydrogen nucleus to fuse with a heavy hydrogen (deuterium) nucleus, with a resultant formation of a variety of helium known as helium 3. From the point of view of the amount of energy released, this fusion is comparable with that which takes place on the explosion of a hydrogen bomb; but unlike the thermonuclear reaction in the bomb, this new process does not involve fantastically high temperatures, the fusion occurring in fact at about 204° C. (400° F.) below zero. Dr. Alvarez pointed out, however, that the catalyst (the mu-meson) was extremely short-lived; it had a life of approximately one-millionth of a second, and perished before it had had time to set up a fusion chain-reaction. He said that if the process was to become of practical importance, it would be necessary to find another catalyzing particle with properties similar to those of the mu-meson but a life of at least ten or twenty minutes. In this context he said it was interesting that Russian scientists had reported evidence that such a particle does exist in cosmic rays. If the search for a suitable catalyzer is successful, this may lead to a simple, effective and inexpensive solution of the problem of controlled thermonuclear fusion, with consequent revolutionary repercussions on the whole question of nuclear power production.[1]

[1] The announcement of this new discovery was reported in *The New York Times* (International Edn.) of 29 December 1956.

¶ *The role of the scientist*

These few examples give some indication of the promise that science holds for the future of mankind. With its aid man will improve his standard of living and realize his hopes of a fuller and more worthy existence. The nuclear scientist may take legitimate pride in being a pioneer of human progress. So far as the conditions under which he is working are concerned, he is, of course, at a great advantage compared with his predecessors. Unlike the men of science of the days of Archimedes and Eratosthenes, who had no equipment with which to verify those daring speculations which still command our admiration, the scientists of our day have at their disposal a wealth of equipment to help them to penetrate the secrets of nature. We can only hope that their research and experiments will be directed exclusively to promoting the welfare of the world as a whole. In this connexion we would quote some words spoken by Professor J. Robert Oppenheimer when addressing the candidates in a scientific examination on 7 March 1950:[1]

'And this brings me to my second wish for you. I wish you not only the joy of great discovery; I wish for you a world of confidence in man and man's humanity, a world of confidence in reason, so that as you work you may be inspired by the hope that what you find will make men freer and better—in which, working as specialists in what may be recondite parts of the intellectual life of the time, you are nevertheless contributing in a direct and basic way to the welfare of mankind.'

4. GENERAL IMPACT OF NUCLEAR POWER

In the first place, what are likely to be the effects of the advent of nuclear power on the utilization of the conventional energy resources?

¶ *Effects on the coal industry*

The development of nuclear science and technique will increasingly make the construction of thermal power stations uneconomic. Coal will cease to be the principal source of energy and its role will be limited to a few specialized industrial

[1] *The Open Mind*, by J. Robert Oppenheimer.

uses. Whereas nuclear power is already competitive with thermal power and there is, as we have seen, every prospect that its cost will progressively fall, the cost of thermal power will gradually rise, for two reasons. Firstly, operational technique in thermal power production has reached a point of development beyond which there is little prospect of further improvements calculated to result in any appreciable lowering of the cost of power from that source. Mr. Hudson R. Searing, President of the Consolidated Edison of New York, told stockholders at the annual general meeting of 1955 that modern technology had almost exhausted the possibilities of lower generating costs through conventional fuels. Secondly, the price of coal will tend to rise in the coming years owing to the increasing cost of mining it.

If the use of nuclear power is extended in the next few years to include space-heating and to provide the heat required in numerous manufacturing processes, the repercussion on the coal industry will be very considerable. The rapid evolution of nuclear technology belies the opinion of the American McKinney panel which, in January 1956, did not anticipate that any serious threat to that industry could arise before about 1980. We believe, on the contrary, that by 1960 the industry will be feeling the effects of the entry of nuclear power into industry, and that from 1965 onwards these effects will become increasingly serious. It seems fairly safe to forecast that towards 1980 there will remain few industrial uses for coal.

¶ *Hydro-electric power*

Up to a certain point much the same might be said about hydro-electric power. Although its production cost is at present lower than that of the other conventional forms of power, in a few years from now it will tend to rise progressively. This opinion was shared by various experts who attended the Geneva atomic conference, particularly those from France. If, as seems certain, technical progress continues at its present rate, it will no longer be prudent to construct dams to serve hydro-electric power stations except in regions where exceptional conditions make this desirable.

Even in parts of the United States where power derived from coal or water resources is abundant and cheap, plans are under consideration for the construction of nuclear plants. In an announcement made on 23 February 1957, Mr. Paul McKee, President of Pacific Power and Light Company, Washington, said: 'The time is coming, when the region (Ohio River Valley) will have to turn to atomic energy to keep up with its rapidly growing power requirements. At present, atomic power is much more expensive than available hydro, but we look for great progress to be made in reducing atomic costs in the foreseeable future and we want to be ready to take action at the proper time.'[1]

¶ *Effects on the oil and natural gas industries*

The oil and natural gas industries will also feel the effects of the industrial exploitation of nuclear power, but to a less marked extent than the coal industry, for the following reasons:

(a) The use of oil for the production of electricity is very limited. Of the total consumption of oil in the United States, only about 2 per cent goes to the generation of electricity.

(b) Motor vehicle propulsion at present absorbs about 41 per cent of all the oil consumed in the United States. While nuclear propulsion for motor vehicles may be unlikely in the foreseeable future, the fact that oil is too dear, particularly in Europe, and that it will not be long before nuclear power is in use for space heating and for marine propulsion, makes it almost certain that within a few years the oil industry will also be suffering the impact of this new form of energy.

¶ *Effects on the railway industry*

Atomic energy development will affect the railways in the following respects:

(a) propulsion of locomotives;
(b) production of electric power for electrified lines;
(c) increase in the volume of traffic resulting from the industrial exploitation of nuclear power.

[1] See article by Gene Smith, entitled 'Atom to compete with Coal and Water', *The New York Times*, 24 February 1957.

It is the third of these factors which will have the most marked effect on the railways.

In many industrialized countries coal is one of the principal commodities transported by rail. It is calculated that, in terms of ton-kilometres, coal accounts for a quarter of total rail traffic in the United States, and the greater part of this coal is used in the generation of electricity. A further point to be noted is that the use of atomic energy will lead to changes in the location of industrial centres, involving in some cases the transfer of existing plants from one centre to another or, in other cases, their abandonment.

¶ *Effects on the uranium industry*

In many countries there has, in the last few years, been a great expansion of capital expenditure on prospecting for uranium and on its extraction and processing. This expansion has been fostered by governments, which buy the uranium ore and guarantee a stable price for it over a given period. The American government has already fixed purchase prices for the period 1958–62, and in this way is encouraging the continued development of the uranium industry.

The future outlook for that industry nevertheless appears highly precarious, for two reasons:

(a) The stability and progress of the industry is dependent on military requirements. If the manufacture of nuclear weapons were to continue and, in addition, nuclear power were increasingly used for non-military purposes, then the prospects of the uranium industry would be assured. If, on the other hand, military demands were to diminish, the outlook for the industry would become very unfavourable, since the satisfying of non-military demands, however extensive they might be, would require the extraction and processing of only a limited quantity of uranium ore, and especially the richer types of ore.

(b) the harnessing of thermonuclear fusion will strike a mortal blow at the uranium industry, rendering its installations worthless.

In other words, a rapid development of nuclear technology resulting in the use of a new nuclear fuel, or a change in the

structure of demand because of diminishing military requirements, would have very serious effects for the uranium industry.

¶ *The necessity for a prudent but dynamic nuclear policy*

In drawing up their nuclear programme, even though it be only of a short-term nature, governments must show a combination of prudence and boldness. The period between now and 1960 will be of vital importance in determining the subsequent trend of atomic development and the future evolution of the world's economic and social structure. The main preconditions for development of the industrial use of atomic energy are intensive nuclear research and the training of specialists and technicians, of whom there is at present a great deficiency. During the period in question the leading atomic countries must invest a great amount of capital which may lose its value even before it has begun to show a return; and they must help other countries with research and the training of personnel.

Quite apart from the possibility that the harnessing of thermonuclear power may be accomplished in the not distant future, nuclear technique has already reached a stage of development which enables even the smaller countries to build nuclear power stations that will generate electricity at a cost less than that of power from thermal stations.

Chapter 7

NUCLEAR POWER AND THE WORLD'S DEMOGRAPHIC PROBLEM

I. THE PRESENT DISEQUILIBRIUM BETWEEN WORLD POPULATION AND WORLD RESOURCES

One of the first questions we must consider is whether this new source of energy can provide an effective solution of the most pressing problem of our age: the population problem.

Before endeavouring to answer this question, we must first briefly examine the demographic problem and the reasons for its present acuteness.

¶ *Two-thirds of the human race live in a state of 'chronic undernourishment'*

Humanity today is passing through a period of major crisis, the fundamental characteristic of which is a persistent state of disequilibrium between the size of the world's population and the amount of natural resources available to support it. A comparison of present world population with the available means of subsistence shows that the average standard of living is extremely low and that, for humanity taken as a whole, that standard cannot be regarded as anything like 'decent'. *Two-thirds* of the human race live in a state of 'chronic undernourishment'. A population of over 1,500 million inhabits the underdeveloped regions which exist in Asia, Africa, Latin America, the Middle East and, indeed, in parts of Europe. This population—the major part of the human race—is badly fed, badly clothed and badly housed.

Various official publications[1] show that a majority of the

[1] Particularly of the F.A.O. and I.L.O.

world's population is living in a state of disquieting and dangerous *distress*. Hunger—not only 'total hunger', but, still more, 'hidden hunger'—causes a disastrous deterioration of man's health. It is not famine which claims the greatest number of victims: the physical and moral degeneration resulting from continued undernourishment is the cause of millions of premature deaths.

It is curious to observe the disinclination of the well-fed to talk about other people's hunger. Governments and authorities deprecate any allusion to the subject and often endeavour to divert the minds of the public from this terrible state of affairs. It almost seems as though a 'conspiracy of silence' had been woven around this painful problem.

Throughout the centuries hunger has been—and still is today—one of the most dangerous political forces. It has often provoked or exacerbated social disorders or civil wars, and at times the conflicts generated by it have assumed world-wide proportions. 'It was hunger that precipitated the French Revolution of 1789,' writes Lord John Boyd Orr. 'The revolutionary "famine years" around 1840 had the same direct cause. The cry of the Chartist mobs in England was "bread or blood". Today (he adds) we are belatedly beginning to see hunger as the most terrible scourge which afflicts the poor, and to recognize this scourge as the fundamental cause of the revolt of the Asiatic peoples against the economic domination of the European powers.'[1]

A veil of moral and economic sophistry has been drawn to hide this human tragedy from the eyes of the world. On the other hand, there is no lack of discussion of other phenomena, and above all of war, which has become 'one of the leitmotives of Western thought', to quote a phrase from *Géopolitique de la faim*, a remarkable book by M. Josué de Castro, a former President of the Council of the F.A.O. 'An attempt has even been made,' says M. de Castro, 'to demonstrate in the light of scientific theories that wars are the necessary fulfilment of some supposed biological law. Hunger, on the other hand, has always been regarded as a concept whose repercussions must not be

[1] Preface to Josué de Castro's *Géopolitique de la faim*, Paris, 1952.

allowed to emerge from the realm of the subconscious, once conscious thought has disdainfully closed its doors on it.'[1]

A study of international policy as pursued in recent years reveals an incredible apathy on the part of the great powers in the face of this growing scourge. It is only necessary to note that during the seven years 1949–56 the Western bloc alone—figures are not available for the Eastern bloc—has devoted the enormous amount of 310,000 million dollars to additional rearmament,[2] whereas during the same period the aid granted by the United Nations for the development of backward countries has been something less than the relatively small amount of 1,000 million dollars.

2. THE INSUFFICIENCY OF WORLD INCOME AND ITS UNEQUAL DISTRIBUTION

What explanation can possibly be put forward for this permanent undernourishment from which the greater part of the human race is suffering?

Here are the three main causes of the evil:

(a) the sum total of all national incomes is insufficient to support the world's population;
(b) apart from its overall insufficiency, this total is unequally distributed amongst the various regions of the world and amongst the various social classes; and
(c) the policy so far adopted has failed to bring about any appreciable increase in world income or to raise the standard of living.

In order to form some idea of the extent of the insufficiency of world income, we have only to note the following calculation. If the average standard of living in Britain be regarded as 'a decent standard'—which in fact it is not—the present volume of world income would have to be *quintupled* to permit of all human beings enjoying the same living conditions as the average Briton. For the world standard of living to rise to anything approaching the average standard to be found in the

[1] Op. cit., p. 25.
[2] According to a United Press Agency report of 18 December 1954.

United States, present world income would have to be *increased about eight times*. These comparisons show how enormous are the disparities in economic progress and how deplorable are the conditions of existence of the greater part of humanity.

In spite of the serious difficulties that are encountered when an attempt is made to compare the national income statistics of different countries, and in spite of the reservations that must be made to allow for the fact that national income calculations do not take into account all the factors which, directly or indirectly, determine the standard of living, 'per capita national income' is still the only available basis for a study of the state of social well-being.

¶ *Two-thirds of the world's population receive only 15 per cent of total world income*

World income is not only insufficient: it is *badly distributed*. Its distribution among the various regions reflects in a striking manner the degree of inequality that exists between industrialized countries and underdeveloped countries. Here are a few facts culled from national income statistics prepared by the United Nations:[1]

(a) *One-third* of the world's population receives less than 5 per cent of total world income, its per capita income being less than 50 dollars per annum;

(b) about *two-thirds* of the world's population receives only 15 per cent of total world income, its per capita income being less than 200 dollars per annum;

(c) *15 per cent* of the world's population enjoy 70 per cent of total world income, in which connexion it may be noted that in the United States per capita income exceeds 1,800 dollars per annum.

This disproportion appears even more striking if one examines the way in which total world income is shared among the different geographical regions. The following table shows the per capita income for the main geographical divisions of the world in 1949:

[1] United Nations: *National Income and its Distribution in Underdeveloped Countries*, 1951.

Region	*Total income (in 1,000 million $)*	*% of world total*	*Per capita income (all countries) in terms of U.S. $*
Africa	14.0	2.6	75
North America	237.0	43.6	1,100
South America	18.0	3.5	170
Asia	58.0	10.5	50
Europe	148.5	27.3	380
U.S.S.R.	59.5	11.0	310
Oceania	7.0	1.5	560
WORLD TOTAL	542.0	100.0	230

Thus, according to this table, North America, which comes first with 1,100 dollars per inhabitant, receives 43.6 per cent of total world income, though its population makes up only 7 per cent of the world's total population. On the other hand, Asia, which contains over half the total population of the globe (53 per cent) produces only *one-tenth* of world income. Asia, Africa and South America, which together contain more than 65 per cent of total world population, receive only slightly over 15 per cent of world income; while the rest of the world—that is to say, 35 per cent of its population—takes nearly 85 per cent of world income.

Another striking disparity is seen if we compare the productive capacity of the United States with that of the world as a whole. The following percentages show the ratio of production in the United States to total world production in 1950:[1]

Coal	41.7	Iron ore	52.0
Crude petroleum	55.6	Copper ore	36.3
Electricity	38.3	Rayon filament yarn	45.2
Wheat	19.3	Cement	34.3
Maize	39.2	Pig iron and ferro-alloys	57.2
Oats	41.4	Crude steel	59.0
Cotton	37.0		

Thus, a single country whose population is not more than 6 per cent of the world population provides about 40 per cent

[1] United Nations: *Statistical Yearbook*, 1952.

of total world production. This disproportion constitutes an anomaly in world economic development and shows how, thanks to modern techniques, to capital investment and to the possession of a qualified labour force, certain regions of the world have outstripped others, even though these latter are not lacking in either natural resources or manpower.

It must also be noted that, not only is world income as a whole insufficient, and unequally distributed among the various regions of the world, but national income is very unequally distributed within the underdeveloped countries. Here the extremes of wealth and poverty are the most striking. In some of these countries, one-tenth of the population takes almost half the national income. In the case of India, for example, V. K. Rao's study of national income led him to the conclusion that in 1932 nearly one-half of urban revenue went to one-tenth of the urban element of the population. The same inequality prevailed in agriculture, where about 50 per cent of the small farmers together held only 10 per cent of the total area under cultivation, whereas a minority of 1 per cent possessed about 16 per cent of that area.[1]

¶ *Population in the year* 2,000

As time goes on the demographic problem becomes increasingly acute, as a result of the acceleration in population growth that has been a feature of the present century. It is estimated that in the year 1650 world population stood at about 545 million. By 1900 the figure had risen to 1,608 million, or, in other words, it had increased by over one thousand million within the space of 250 years. By 1950 the world's population had reached 2,454 million, which means that it had grown by 846 million in only fifty years. It is increasing at present at the rate of 30 to 35 million a year, equivalent to a daily increase of about 100,000.

If the trend that has been noticeable since 1950 should continue, the highest of three estimates made by the Population Section of the United Nations Organization forecasts that by 1980 world population will have risen to nearly four thousand

[1] *The National Income of British India*, 1931-32, p. 189.

million (3,990,000,000).[1] In other words, the increase *within a single generation* will have been almost as great as that which took place *between the origins of humanity and the year* 1900. By the year 2000 the total population of the globe will have reached five thousand million,[2] or more than double the present figure. By the year 2050 it will be about eleven thousand million.

One may be sceptical as to the possibility of anything approaching accuracy in such forecasts. It may be that the rate of increase will be less than assumed in the above estimates. The one fact, however, about which there is no doubt is that the actual rate of increase at the present time is much more rapid than ever before, and that it constitutes an economic and social problem of a gravity hitherto unknown.

Stress must also be laid on another trend that is now apparent in the movement of world population figures. Whereas during the latter part of the nineteenth century and the beginning of the twentieth the population of Europe and America was growing rapidly, that of Asia and Africa was increasing only slowly. Today the reverse is the case. The rate of increase, particularly since 1930, is greater in the underdeveloped regions than in the industrial areas. The present gap between death rates and birth rates in the underdeveloped countries is, in fact, so wide that in all probability the structure of world population in the year 2000 will be vastly different from what it is today.

3. CAN THE EARTH FEED ITS POPULATION?
MALTHUS AND MARX

Given the present rate of population growth and the volume of world income, what is the outlook for the near future as regards the earth's capacity to feed all human beings? This is a vital question that ought to be seriously occupying the minds of the governments of all countries.

Many people take a gloomy view of humanity's future. They believe that, if population growth continues at the present rate

[1] See United Nations, *The Determinants and Consequences of Population Trends, Series A, Population Studies*, New York, 1953, p. 404 et seq.

[2] According to an estimate based on an annual increase of $1\frac{1}{2}\%$, which can be regarded as normal and probable.

of 30 to 35 million a year, the time must inevitably arrive when world resources will be insufficient to support the world's population, and that the hunger and misery which will ensue will in due course arrest that growth. The partisans of this neo-Malthusian theory maintain that there is but one way of preventing this course of evolution, namely, to slow down the rate of population growth by means of *compulsory birth control.*

¶ *Malthus on restriction of the population*

In order to understand the neo-Malthusian theory, which has a considerable vogue at the moment, we must go back to the English economist, Thomas Robert Malthus, who was the first to point out the danger of over-population. About 150 years ago, in his famous work, *An Essay on the Principle of Population,* the first edition of which appeared in 1798, Malthus propounded the theory that population, if unchecked, tends to increase in a geometrical ratio, whereas production of the means of subsistence increases only in an arithmetical ratio. He saw in this inexorable increase in population a grave threat to the world's economic balance, and he regarded poverty as the inevitable consequence of this increase. In order to prevent the misery of poverty, Malthus counselled 'moral restraint' on the part of the population, in the sense that people should abstain from marriage until they are in a position to support a family.

Developments since Malthus' time have shown that he over-simplified the laws of population and progress, as well as their interdependence. Above all, he confused a mere physiological 'possibility' of population growth with 'an actual trend', and he did not take into account either the economic and hygienic obstacles to growth, or technological progress, or the changes that take place in the social structure of every country. Malthus postulated that population would double every 25 years. If he had been right, the population of the world would now have been much greater than it actually is. Further, experience has shown that in certain countries, such as the United States and the Soviet Union, the rate at which production increases may—even very considerably, and over a long period of years—outstrip the rate of population growth. In the United States,

industrial production increased during the 40 years from 1899 to 1939 by 273 per cent, while the population, notwithstanding the large influx of immigrants, increased by only 75 per cent. In the Soviet Union, the 25 years from 1913 to 1938 witnessed an increase of 310 per cent in industrial production and one of only 20 per cent in the population.

Instead of the famine foreseen by Malthus, therefore, certain countries have seen their production increase to a proportionately greater extent than their population. The situation has even arisen (paradoxical, indeed, yet typical of the contradictions inherent in the capitalist system) in which, as for example in the nineteen-thirties, the consumer demand for certain products dried up and the products were actually burnt in order to prevent prices from slumping. It should also be noted that at the present time surplus stocks of some commodities are piling up in various parts of the world. According to the F.A.O., the stocks of wheat held by the four main exporting countries (the United States, Canada, Australia and Argentina) increased in 1953/54 by some 12 million tons, or by 33 per cent, and represented about two and a half times their current annual level of wheat exports.

¶ *Marx rejects Malthus' theory*

The Malthusian theory was denounced by Karl Marx, who maintained that there can be no such thing as surplus population in a properly organized social system. According to Marxist theory, a population and its changes and structure are determined by the economic and social conditions in which that population lives. Marx held that demographic pressure and over-population are the results of the capitalist system, which prefers to keep a certain proportion of the labour force inactive in order to ensure the profitability of business enterprise. He thus regarded unemployment and underemployment as characteristic features of the capitalist system, and affirmed, on the other hand, that socialism is the only system which can ensure the most effective utilization of human and natural resources and a constant improvement in the standard of living.

Marx was probably right in thinking that the problem of

over-population can be eliminated subject to certain conditions. A socialized economy, functioning according to a well-conceived economic plan, would ensure full employment and a rate of increase in national income far more rapid than the rate of population growth.

In supporting the opposite theory, however, the neo-Malthusians are perhaps themselves not far from the truth when they assess the demographic problem in the light of present data. Indeed, if one considers the present standard of living, which is very low, the decrease in total food supplies as compared with the period before the war, and the accelerated rate of population growth, one may well wonder whether there is any room for optimism. If the earth cannot provide adequate sustenance for its present population of some 2,500 millions, how will it be able, at the present rate of economic development, to satisfy the needs of a population which by 1980 will have risen to about 4,000 million?

¶ *The fears of the neo-Malthusians*

This is the nightmare of a number of demographers, whose fears appear to be confirmed by the statements made by the competent organizations.

Here, in this connexion, is an extract from a report published by the United Nations:[1]

'For many regions, and for many foodstuffs, especially of animal origin, the increases needed to meet these requirements are far beyond what are possible for a number of years to come. Even a moderate advance towards better nutritional levels for the world as a whole within a reasonable time is a formidable problem.'

Similar fears are expressed by the British Royal Commission on Population in its report issued in 1949, in paragraph 423 of which we read:

'In the conditions that have obtained since the nineteenth century some form of control over numbers was inevitable. Unless famine, disease or war multiplied our death rates, the nineteenth century size of family would double the population in

[1] United Nations: *Preliminary Report on the World Social Situation*, 1952.

less than thirty years and increase it a thousandfold in less than 300 years. Such a rate of growth is clearly out of the question. The real issue in our view is the means by which control of the rate of population growth is achieved.'

Another British organization, PEP (Political and Economic Planning), on the occasion of the World Population Conference held at Rome in September 1954, published two brochures which formulate some pessimistic conclusions from which we quote the following extracts:[1]

'Analysis of the highest rates of increase in food production yet attained in the most favourable circumstances, and of foreseeable technical improvements, discloses no sound basis for the widely held view that production will more or less automatically keep pace with the needs of growing population.'

'Policies deliberately framed to adjust population to resources must some time be necessary.'

Some of the delegates present at the World Population Conference at Rome emphasized the danger which menaces the human race by reason of the very rapid rate of population growth. All these specialists, while not entirely accepting Malthus' arguments, regard birth control as the only possible means of keeping population growth in check.

4. THE CHOICE BETWEEN POVERTY AND PROSPERITY

The fundamental error of the neo-Malthusians arises from the *narrowness* of their point of view: their eyes are turned to the past and are blind to the potentialities of the future. Instead of admitting the bankruptcy of an outworn policy and demanding more rational and effective methods, they still trot out the old arguments to prove the 'insufficiency' of the world's resources. It is true that if we compare the *very slow* rate at which production is at present increasing with the acceleration in the rate of population growth, the conclusion cannot fail to be pessimistic.

The solution is not that the population should adapt its size to the level of production, but that economic development

[1] *World Population and Resources*, and *Controlling Human Numbers*, PEP Series PLANNING Nos. 362 and 367 (1954).

should keep pace with the growth of population. We cannot read the future by looking backwards, for we shall be ignoring the new possibilities which lie ahead. Like Malthus himself, the neo-Malthusians have a horror of social reforms or of anything that might radically modify the economic status quo. Malthus was opposed to social reforms because he believed they would only make matters worse. He condemned socialism in whatever form, and demanded the abolition of the Poor Law on the ground that any state assistance for the poor would only cause their number to multiply. In the 1803 edition of his famous work, he wrote the following 'condamnation effrayante' (to quote the expression used by his disciple, J. Garnier):

'A man who is born into a world already possessed, if he cannot get subsistence from his parents on whom he has a just demand, and if the society do not want his labour, has no claim of right to the smallest portion of food, and, in fact, has no business to be where he is. At Nature's mighty feast there is no vacant cover for him. She tells him to be gone, and will quickly execute her own orders, if he do not work upon the compassion of some of her guests.'

An equally inhuman utterance was made some 150 years later by one of Malthus' disciples. Here is what a prominent neo-Malthusian, William Vogt, wrote in 1948 about China:[1]

'There is little hope that the world will escape the horror of extensive famines in China within the next few years. But from the world point of view, these may be not only desirable but indispensable.'

Present developments in China do not, however, appear to justify such sinister predictions.

The old Malthusian argumentation is thus still being used by the neo-Malthusians. They are on principle against any policy designed to bring about a socially equitable redistribution of national income. They are opposed to any reform of the social structure and to any change in the economic system.

A policy which is based on outworn principles, which is designed to serve the interests of certain social classes, and which is characterized by immobility, can only result in a slowing up

[1] *Road to Survival*, 1948.

of economic development, an insignificant increase in world income, and the perpetuation of social inequalities and of a very low standard of life. A British economist, Thomas Balogh, in a survey of world economic progress, arrives at the following conclusion:[1]

'If progress in what one might call the "average income" countries was very uncertain, and inadequate to bring about a better state of balance in world economy, the situation in the poorest regions which contain the great majority of the population of the non-Soviet world was disastrous. It seems questionable whether total real production per inhabitant outside the Soviet Union is at present any higher than in 1913, or even than in 1900. Moreover, far from having been checked, this trend seems to have been *accelerated* by the second world war.'

The same is true, adds Mr. Balogh, as regards industrial production, for 'it is surprising to note that, outside the richest regions and the Soviet world, the increase from 1938 to 1952 was only 10 per cent, as compared with an increase of 20 per cent in population.'

A *radical and revolutionary modification* of present policy is therefore *essential.* If we change methods, if we effect structural reforms, if capital resources are made available on a sufficiently large scale for the development of the backward countries, and if we adopt a new economic and social policy, then world resources will become sufficient to satisfy the needs of the whole population of the globe, even though those needs should increase and become more and more complex. If these changes can be brought about, we can confidently anticipate a spectacular increase in food production and industrial output and an appreciable and progressive improvement in the standard of living. Marx's optimistic theory will then have been found justified. If, on the other hand, the world continues to cling to the old, outworn systems, world resources will be found insufficient to provide the whole of the human race with a decent level of existence, and hunger will continue to be the world's most terrible scourge. In that event Malthus' pessimistic theory

[1] Thomas Balogh: 'Déséquilibre des forces économiques', in *Revue Economique* Paris, No. 5, September 1955, p. 703.

will have found its justification.[1] It is for man himself to choose between the path of prosperity and that which leads to poverty and misery. The advent of atomic energy can radically modify the whole aspect of the problem.

[1] Among contemporary demographers who have shown a rational approach to this problem, mention should be made of M. Alfred Sauvy, Director of the Institut National d'Etudes Démographiques (France). See in particular his *Théorie Générale de la Population*, Vol. I, 'Economie et Population', Paris, 1952. See also Harold Wilson, *The War on World Poverty*, London, 1953.

Chapter 8

TOWARDS A REDISTRIBUTION OF WORLD WEALTH

I. UNEXPLOITED ECONOMIC POTENTIALITY

Wealth cannot be created by energy alone: it also presupposes the existence of unexploited natural resources. Apart from the sources of energy itself, are the world's resources *sufficient* to support its population? Is there enough cultivable land, and are there sufficient raw materials, to satisfy in a reasonably adequate manner the needs of the world's constantly growing population?

Are there first of all margins for a considerable expansion of agricultural production? Experiments in a number of countries have led to a great improvement in methods of cultivation, to an appreciable increase in the productivity of the soil and, in general, to an increase of more than one-third in agricultural production within a very short space of time. A few examples will suffice to show the extent to which the possibilities offered by modern techniques are being *neglected*. At present, average world production of wheat varies between 9 and 11 quintals per hectare and that of rice between 14 and 16 quintals. In those regions, however, where improved farming techniques are employed, the yield per hectare has risen to 20–30 quintals for wheat and to 40–50 quintals for rice.[1] In this connexion, attention may be drawn to a recent statement by the United States Ministry of Agriculture. Referring to the great increase in

[1] Productivity reaches even higher levels in countries like the United States and the Soviet Union. At the World Population Congress held at Rome in September 1954, T. U. Ryabushkin stated that in the Soviet Union a yield of over 100 quintals per hectare had been attained for wheat and over 170 quintals for rice. (See his report: 'Social Aspects of Population Structure and Movement', E/Conf. 13/382.)

productivity, due for the most part to the introduction of new farming techniques, the Ministry said that in each of the five successive harvests from 1942 to 1946 American farmers had produced enough foodstuffs to feed about 50 million more people than was the case in the five harvests preceding 1930.

Would it not be possible by the generalization of the use of these techniques to secure an enormous increase in world agricultural production? The economist, Colin Clark, maintains that, by the adoption of scientific and rationalized farming methods, the part of the earth's surface which is already under cultivation could be made to produce sufficient food to satisfy the requirements of the world's growing population. Apart from what could be achieved in the way of improving the yield of land already cultivated, a considerable increase in production could be obtained by bringing fallow land and hitherto arid regions under cultivation. It is estimated that, in fact, only one-eighth of the cultivable surface of the globe is at present being cultivated. St. Rauchenburg estimates that even if the population of the underdeveloped regions of the world increased from 1,650 million (in 1950) to 2,520 million by the year 2000, those regions could not only support an increase of this order, but could raise the daily intake of calories per person from the present figure of 2,000 to 2,900.[1]

Some idea of the immense scope still left for the expansion of agricultural production, particularly in the underdeveloped countries, can be gained from the following figures showing the distribution of cultivable land, population and agricultural production among the world's main geographical divisions:

DISTRIBUTION (1934-1938)
IN PERCENTAGES OF WORLD TOTALS[2]

Region	*Cultivable land*	*Population*	*Value of agricultural production*	*Index of return on capital*
World	100.0	100.0	100.0	100.0
North America	14.8	6.6	15.9	242
Central and South America	16.0	6.0	8.8	147
Europe	4.1	18.3	29.6	160
U.S.S.R.	15.9	7.9	11.9	151
Asia	20.3	53.5	27.4	51
Africa	22.5	7.2	3.6	50
Oceania	6.4	0.5	2.8	567

[1] *People, Food, Machines*, Washington, 1950.

[2] This table is reproduced from the International Institute of Agriculture's publication: *Agricultural Commodities and Raw Materials*, Rome, 1949.

If a comparison be made on the basis of agricultural production per inhabitant, we find that in the United States it is 2.4 times greater than the average for the whole world, while in Asia and Africa it is not more than half that average. In the case of these two continents this situation is not due to laziness on the part of the farming community or to poorer soil, but exclusively to the non-utilization of modern techniques. A recent report published by the United Nations states that, prior to the rise of modern science and the development of scientific agriculture in western countries, agriculture in Asia was 'perhaps the world's best, from the point of view both of efficiency and of the kind and quality of its products.'[1]

There is no reason, therefore, why the countries of Asia should not attain the same levels of agricultural production as are to be found in the developed regions of the world. It may here be noted that in the last five years China has already trebled its production of cotton and no longer needs to import any from abroad.

¶ *The industrialization of the underdeveloped countries*

The industrialization of the underdeveloped countries is the most effective means of providing employment for their surplus agricultural population, of absorbing unemployment of whatever type, and of appreciably increasing national income. The example of the United States and of other countries proves that the possibilities of increasing a nation's wealth are enormous. The population of the United States, from a mere 5 million in 1800, had risen to 150 million by 1950. This fact shows that economic development in the United States would have been much less rapid had not a continuous and massive immigration

[1] *Economic Study of Asia and the Far East, 1950*, New York, 1951, p. 4.

provided *the new manpower needed for the exploitation of the country's natural resources.*

If the known reserves of minerals and other raw materials are scattered unevenly throughout the world, this does not mean that certain countries are lacking in such resources, but that the economic potential of those countries has not yet been sufficiently explored. In the United Nations' above-mentioned *Economic Study of Asia and the Far East* we read:

'The knowledge of mineral reserves in the region is admittedly far from being adequate, partly because such knowledge is a function of the extent to which mineral resources have been utilized, and partly because the geological investigation and mineral exploration so far undertaken have been neither intensive nor extensive.'[1]

Experts tell us that the world's total resources of raw materials are adequate to cover all requirements for very many years to come, and that new minerals are constantly being discovered. According to the American Institute of Mining and Metallurgical Engineers, 34 new minerals were brought into use between the two world-wars. Further, new techniques are prolonging the life of existing materials, are making use of materials not hitherto employed in industry, and are cutting down the use of rare materials and replacing them by others that are more abundant.

Certain experts anticipate that industry will in fact evolve in such a manner that mineral resources will eventually become much less indispensable than they are at present. An American geo-chemist, Mr. Harrison Brown, whose researches won the praise of Albert Einstein, forecasts that 'the basic raw materials for the industries of the future will be seawater, air, ordinary rock, sedimentary deposits of limestone and phosphate rock, and sunlight.' All the ingredients essential to a highly industrialized society are, he says, present in the combination of those substances.[2]

There appears every reason to believe that the possibilities of increasing world income are immense. Seen from the level

[1] Op. cit., p. 30.
[2] Harrison Brown: *The Challenge of Man's Future,* London, 1954, p. 218.

at present reached in science and technology, a brilliant vista opens up for humanity provided it shows itself capable of making good use of those possibilities.

2. THE ROLE OF NUCLEAR POWER IN THE INDUSTRIALIZED COUNTRIES

The exploitation of the immense possibilities that nature places at man's disposal will be greatly facilitated by the use of nuclear power. If energy in general constitutes, as we have seen, a factor of economic development, then nuclear power with its immense potentialities may, if rationally utilized, become a factor of primary importance in the execution of a planned policy for the exploitation of latent resources. The results achieved by the use of nuclear power will vary according to where it is used (industrialized, agricultural or underdeveloped countries). These results, which will be both direct and indirect, cannot be forecast with any exactitude. Economic history shows that technical innovations have never exercised a symmetrical or proportional effect on different national economies. The effect depends on a variety of factors, such as the nature of the particular economic system, opposition to the exploitation of new inventions, competition between different countries or groups of countries, etc. In any case, however, this new invention will undoubtedly have effects far transcending those produced by all the inventions the world has hitherto known.

¶ *The direct effects*

We will endeavour to assess very approximately some probable repercussions of the use of nuclear power, beginning with the industrialized countries.[1]

Let us consider in the first place the *direct* effects. The primary

[1] Among works on this subject that have been published in the United States during the past few years, particular mention may be made of two. The first is a report issued by the Cowles Commission for Research in Economics, of the University of Chicago, prepared under the direction of Sam H. Schurr and Jacob Marschak (published for the Cowles Commission by Princeton University Press, 1950). The second, entitled *Atomic Power, an Economic and Social Analysis,* was written by an economist, Dr. W. Isard, of the University of Harvard, and a sociologist, Dr. V. Whitney, of Brown University (New York, 1952). As we shall see later, these two works put forward interesting estimates of the probable repercussions of the use of nuclear power in a 'capitalist economy'.

result of the utilization of a new and better motive power is a more extensive exploitation of national resources, and this in turn provides the basis for new economic activities and an increase in national income. The extent of this increase will depend largely on the degree to which nuclear power is cheaper than power from the conventional sources. Taking as a basis the level of national income in 1946, and the volume of power consumption in that year, the Cowles Commission estimated that a reduction of 1 mill per kwh would mean a saving of 240 million dollars, while if the reduction were $2\frac{1}{2}$ mills per kwh, the amount saved would be 600 million dollars.

The same subject has been studied by W. Isard and V. Whitney. On the assumption that the cost of nuclear power might possibly fall to zero, these authors arrive at the conclusion that industrial output might increase annually by 5.3 per cent. They even go so far as to admit that, theoretically, the increase might be as high as about 10 per cent.[1]

This increase will vary according to the particular branch of industry concerned. Both the Cowles Commission and Messrs. Isard and Whitney have prepared a series of estimates of the probable repercussions of nuclear power on production costs in the industries producing aluminium, iron and steel, fertilizers, etc. In agriculture and transport the direct effects of the use of nuclear power will be different. Everything will depend, in fact, on the incidence of nuclear power on the costs structure of each particular activity. There will be important repercussions as regards the regional distribution of industry and the distribution of manpower. It will become possible to establish new industries in areas where exploitation of local resources and raw materials has hitherto been impossible owing to lack of electric power.

Further, the entry of the atom into economic life will reduce the importance of the conventional sources of power, and particularly of coal. A considerable part of the manpower at present employed in mining will have to be transferred to other employment. Limitation of working hours will become an imperative necessity in the atomic age.

[1] Isard and Whitney: *Atomic Power, an Economic and Social Analysis.*

¶ *The indirect effects*

In general it may be said that the indirect effects of the use of nuclear power in industrialized countries will be more marked than the direct effects. The availability of a cheaper supply of power will in the first place encourage activity in sectors of the economy in which power is an important element in production costs. Another probable effect will be development of activities that have not hitherto been profitable. Further, one should not underestimate the effect that generalization of the use of cheap nuclear power must have on the introduction of new techniques and, finally, on the structure of production costs throughout the national economy.

This new motive power will permit of the introduction of production processes that are at present impracticable; it will provide an unprecedented stimulus to technological progress. In this connexion one has only to consider the prodigious development that took place in the steel, glass, rubber and other industries following the introduction of the steam engine and of electricity. One must also consider the secondary effects indirectly produced by the generalized use of nuclear power, namely increased production and consumption throughout the economy. The Cowles Commission's report discusses the incidence of the 'multiplier' factor on the production process and on consumption, and puts the coefficient at 2.5. Here energy plays the part of a stimulant and encourages various activities which in turn have widespread and complex consequences. The secondary effects are even more marked in the tertiary activities (transport, public services, trade, etc.) which have an important influence on national income. Mention must also be made of the great advantages that agriculture, even in the advanced countries, will derive from the use of nuclear power and of radioisotopes. The reduction of losses due to plant diseases, pests and spoilage, and the adoption of various improved techniques will considerably increase the productivity of already cultivated areas, quite apart from the additional yield that could be obtained by bringing new areas into cultivation with the aid of this new source of power. Radioisotopes also render inestimable services to science and medicine.

Finally, the generalization of the use of nuclear power will have vast social repercussions by reason of the fact that working hours will be shortened and the workers will have more leisure for recreation and the enjoyment of life.

¶ *Towards a new industrial map*

It would be a mistake, however, to set too narrow limits to our contemplation of the repercussions of the use of nuclear power, and to fail to appreciate the universal and revolutionary role that this power is destined to play in the world in which we live.

We must first of all understand that it is a question, not of an evolution of technology, but of an industrial revolution on a scale that the world has never yet known. The steam engine, the internal combustion engine, hydro and thermal electricity, electronics: all these are stages in a continuous process of technical evolution that began in the eighteenth century. With the advent of nuclear power, however, an entirely new age begins. President Truman rightly emphasized the revolutionary character of this great conquest of science when, on the occasion of the keel-laying of the first atomic-powered submarine on 14 June 1952, he said:

'The engine of the *Nautilus* will have as revolutionary an effect on the navies of the world as did the first ocean steamship 120 years ago.'

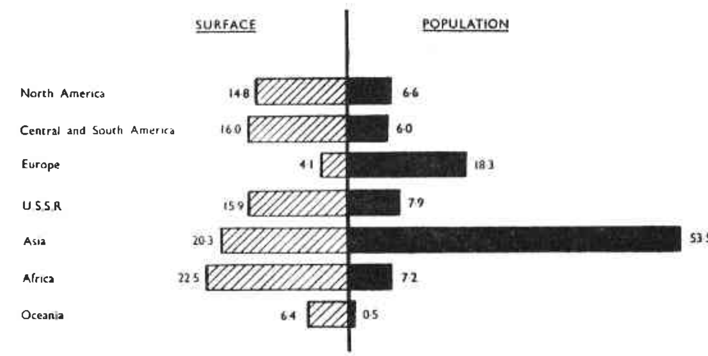
It would also be a mistake to limit our consideration of the repercussions of the use of nuclear power to a comparison of the respective costs of the various kinds of energy. The most important consequence of its use will be a far-reaching modification of the economic map, not only of individual countries but of the world as a whole. One of the most important features of nuclear power lies in the fact that it will make it possible in the future to produce electricity wherever it may be required and at a cost which will not depend on the place of production. As the fissile material used in nuclear reactors can be transported easily and at negligible expense, the availability of nuclear power will permit of the creation of new industries in regions where this has hitherto been out of the question. In present conditions, the problem of power supplies necessitates the topo-

graphical concentration of the large industrial enterprises, particularly around the coal mines and hydro-electric power stations. It is easy to understand, therefore, how existing enterprises will be affected by the coming modification of the distribution of economic activity. But this is a point to which we must return in the next chapter.

3. NUCLEAR POWER IN THE SERVICE OF THE UNDERDEVELOPED COUNTRIES

It is in the underdeveloped countries that nuclear power is destined to render the greatest service in the exploitation of economic potentialities. From what is already known about the process whereby electric power can be generated from nuclear

SURFACE AND POPULATION OF THE EARTH
Distribution by regions
(in percentages of the total)



energy, and about the cost of such power, it is clear that the underdeveloped countries can obtain all the electric power they need as soon as the 'atomic countries' are able and prepared to supply them with the necessary equipment.

The cost of electric power in the underdeveloped countries is at present so high that they are unable to produce anything like the quantity they need. Long distances, defective communications and the lack of energy sources are adverse factors

which at present increase the cost per kwh of power produced in those countries and maintain their economy in a primitive stage. The great advantage of nuclear power is that the means for its production can be transported easily and rapidly to any part of the world, however remote.

Addressing a meeting of representatives of Swiss electrical industries, M. Alfred Winiger said: 'A ton of uranium, used to the maximum, produces as much heat as 3 million tons of coal. To transport this coal from the mines of the Ruhr to Zürich would alone cost nearly 120 million Swiss francs, plus the cost of storage.'[1] And that is for a country situated in the heart of Europe.

How impossible, therefore, is the present position of those underdeveloped countries which are situated far from the sources of electric power! In South Africa, for example, coal has to be transported over such a long distance that its price is doubled by the freight charge. The important consideration for such countries is not the cost of electric power, *but the actual availability of sources of power*. If, therefore, the raw material of nuclear power can now be transported to those countries rapidly and at an insignificant cost, the prospects for their economic development assume an entirely new aspect. Regions which are rich in natural resources, but are at present unable to exploit them for lack of electric power, will in future be enabled to transform those resources locally into finished products and export them.

¶ *Nuclear power stations in underdeveloped countries*

A price of 0.6d. per kwh of nuclear power in Great Britain, or of 7 to 10 mills in the United States, is not regarded as particularly advantageous in comparison with the price of conventional power. For the underdeveloped countries, however, such a price is so low compared with that of conventional power that the availability of power at that price would transform the problem of their economic development. According to a statement by Sir Edwin Plowden, Chairman of the U.K. Atomic

[1] *The UNESCO Courier*, Special Number No. 12, 1954, entitled 'The Promise of Atomic Power', p. 11.

Energy Authority, an investigation of the production costs of 40 diesel power-stations of 5,000 kilowatt capacity showed that the average worked out at 1.9d. (22 mills) per kilowatt-hour. In the case of some of these stations, the cost was as high as 2.6d. (30 mills).[1] The fact that the cost of a nuclear power station is at present about double that of an ordinary power station is not an insuperable obstacle. Part of the additional expense would be offset by the difference between the production cost of conventional power and that of nuclear power, quite apart from the fact that the operating costs of a nuclear power station would be less than in an industrialized country.

It should further be noted that the experts anticipate that the capital cost of a nuclear power station will decrease considerably in the future. Countries which cannot build their own nuclear power plants will be able to buy them from the major atomic countries at a cost which would include the price of a complete reactor, the supply of fresh nuclear fuel and the return of irradiated elements for re-processing. On this basis the initial capital expenditure would be about £20 million, and for a smaller station about half that sum. Mention should also be made of the so-called 'packaged' reactor, which does not need large quantities of water for cooling purposes. Such a plant, with a capacity of 10,000 kilowatts, could be used for driving a gas turbine, and would be of great utility in regions which are destitute of the conventional sources of power.

Great Britain is prepared to construct in the underdeveloped countries 50,000 kilowatt power stations which, at the present stage of technique, would produce electricity at a cost of 1.35d. per kilowatt-hour, i.e. at appreciably less than the present average cost of 1.9d.

There is one further advantage which, in the case of the underdeveloped countries, would largely offset any excess of the cost of nuclear power over that of ordinary power. The utilization of the nuclear power on the spot would economize much capital which would otherwise have to be spent on building railways for the transport of coal and ores, and which could be used for the construction of nuclear power stations.

[1] Panel Discussion on Atomic Energy, op. cit. p. 8.

¶ *The effects on agriculture*

The scope for the utilization of nuclear power will not be limited to the industrial sphere. It will also play an important part in the development of agriculture. We have already referred to the numerous services that radioisotopes can render to agriculture. Some experts go so far as to assert that the use of nuclear power will yield more substantial results in agriculture than in industry. The possibilities in the former sector are indeed vast. In the first place, nuclear power will make it possible to bring into cultivation numerous arid regions in Africa, Asia, Australia and America. Several experts at the Geneva conference stressed this particular potentiality of nuclear power. With its aid demineralization of seawater could be undertaken on a sufficient scale to make possible the irrigation of waterless regions situated near to the sea. The scientists will be able with the aid of radioactivity to extend the present bounds of cultivation to the poles and the deserts. 'The applications of radioisotopes and radiation to problems of concern to agriculture are limited only by the imagination and ingenuity of the investigators,' remarks the F.A.O. in a paper presented at the Geneva conference.[1] And when the scientists, with the aid of radioisotopes, finally discover the secrets of photosynthesis—the process whereby plants capture and use the sun's rays—the world's food problem may be completely transformed.

¶ *Plans for accelerated development*

In order, however, to appreciate the immense contribution that energy, and particularly nuclear energy, can make in the development of the backward countries, we must take into consideration a factor which only a few years ago was virtually non-existent, namely, the intense desire of the peoples of these countries to secure a rapid increase in their production of material goods and an improvement in their standard of living. These peoples, who are at present poorly fed, clothed and housed, realize that the improvement of their conditions will call not only for aid from other countries, but for the

[1] Document P/780: 'The Uses of Atomic Energy in Food and Agriculture'.

mobilization of their own resources and efforts and the acceptance by them of inevitable sacrifices. The Prime Minister of India, Mr. Nehru, made the following statement at the Bandoeng conference:

'We have agreed that economic aid from abroad cannot be of very great use if these countries are incapable of developing their resources themselves. It is essential that they should supply their own wants, and austerity will for the time being be the pre-condition of future prosperity.'

There can indeed be no economic progress in these countries unless their populations are willing to make the necessary efforts, and unless the state organization is such as will make development possible. Since the war many countries have shown a passionate desire for a radical change in their conditions of life and for a rational development of their countries' economic potentialities. They are preparing development plans, mobilizing their national resources, and co-ordinating their activities in order to achieve this objective. In this connexion mention may be made in particular of the Asiatic 'giants', India and China, who, by means of five-year plans, are endeavouring to accelerate their development in order to catch up with the great Western powers. The objective of China's first five-year plan (1953–7) was 'to transform this agricultural country into an industrial power', increasing overall industrial production by 98.3 per cent. The second five-year plan (1958–62) contemplates an increase of 50 per cent in the national income.

India also has adopted the five-year plan system. The first Indian plan—that for the period 1952–6—had as its primary aim the development of agriculture, irrigation and the production of electric power.[1] The main objective of the second plan (1957–61) is the acceleration of industrial development, accompanied by an increase of 55 per cent in the national income. India attaches particular importance to the development of heavy industry. The 1957–61 plan contemplates the construction of three steelworks, and estimates that by 1961 steel production will have been raised from 1,200,000 to 6,000,000 tons per annum.

[1] Government of India: 'The First Five-Year Plan', Delhi, 1953.

If these countries are already developing their economies at this rate in spite of the difficulties they experience owing to the lack of adequate supplies of electric power, one can easily imagine how their progress will be accelerated when nuclear power becomes available to them. If within a few years the harnessing of thermonuclear fusion becomes a reality, the present economic gap between the industrialized and the underdeveloped countries will very rapidly narrow.

¶ *The question of finance*

The development of the backward countries would undoubtedly be facilitated and expedited if financial aid were forthcoming from the industrialized countries. In Chapter 10 we shall show how this aid could be made available. It would, however, be a great mistake to assume that external financing is a *sine qua non* of such development.

In his address at Geneva on the subject of the future of atomic energy, Sir John Cockcroft, when referring to the question of the use of atomic energy in underdeveloped countries, said, however, that atomic energy alone could not assure prosperity, for 'what those countries would need above all would be capital, technical development and agriculture'. Apart from the problem of technology, for which a solution ought to be possible through international co-operation, the problem of investment capital is not in our opinion as important as some people appear to believe. When one talks of 'available capital' in the case of an underdeveloped country, one is thinking primarily of foreign capital. Even though it be true that foreign capital may in certain conditions facilitate and even accelerate the economic development of a country, it is none the less a mistake to assume that the absence of this capital may make such development impossible.

The crucial factor for economic development is the volume of capital investment. The more capital is invested, the greater will be the growth of production. Whence is this investment capital derived? In the first place, from savings: it consists of that part of national income which is not consumed. Each government should decide, under its economic policy as

embodied in and implemented through an economic plan, how much of the national income shall be consumed and how much shall be saved and made available for investment. A country that wishes to accelerate its industrialization and increase its production and income must devote a large part of its national income to investment and, if necessary, limit consumption. After the Second World War many countries —prominent among them being the Scandinavian countries and the United Kingdom—adopted a policy which aimed at fostering investment. That policy has shown very satisfactory results. This problem of the financing of investment is essentially one for the government of each individual country. If a government shows itself incapable of formulating and applying a suitable policy, even a large amount of financial aid from abroad will be of no avail. Underdeveloped countries like India and China have, out of their own resources, achieved results which a few years ago would have been considered impossible. Consider the following figures. India's first five-year plan laid it down that during the period of the plan 20 per cent of the yearly increase in national income should be devoted to capital investment, so that by the end of the fifth year such investment would absorb 6¾ per cent of the national income.[1] Although this percentage is much lower than that reached in industrialized countries, it none the less represents a considerable achievement for a country in which the volume of investment has hitherto been quite insignificant. The volume of capital investment will be approximately doubled under the second five-year plan, rising from U.S. $5,000 million to $10,000 million. The part of the national income that is devoted to capital investment is still greater under China's economic plans, which contemplate a proportion of 20 per cent. The first five-year plan allocated $33,000 million for this purpose, while the second envisages the expenditure of about twice this amount ($65,000 million).

The example of the Soviet Union proves that communist countries are able to solve the problem of the financing of capital investment without recourse to foreign capital. In a

[1] Government of India: 'The First Five-Year Plan', 1953, p. 15.

comparative study of the Soviet and the American economic potential, the American economist, Philip E. Mosely, writes:[1]

'The most important result of Russia's new position as the second strongest industrial power is that the Soviet method of industrialization offers an alternative to the Western or American method. The Bolsheviks have shown what can be accomplished in a backward country, rich in raw materials and manpower and poor in capital and technology, under the ruthless drive of communist dictatorship.'

As regards the installation of nuclear power stations in the underdeveloped countries, this will be facilitated by assistance from the major atomic countries, which will compete with one another for contracts to supply the underdeveloped countries, on the most favourable terms, with the equipment needed for the production of nuclear power. Both the United States and the Soviet Union have already concluded a series of bilateral nuclear agreements and have begun to deliver reactors to certain countries. The fact that they are prepared to give assistance in the nuclear sphere to countries which need it shows that the problem of finance does not constitute an obstacle to the utilization of atomic energy by the underdeveloped countries.

¶ *A new geopolitical map of the world: the emergence of Asia*

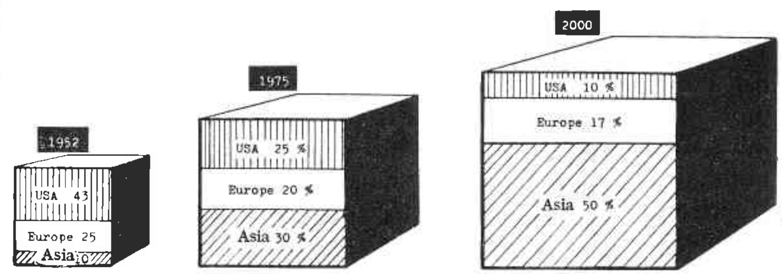
In the light of what has been said above it appears reasonable to conclude that atomic energy will bring about far-reaching structural changes in the underdeveloped countries: it will make possible economic progress, and the present low standard of existence will be replaced by a steadily rising level of prosperity. If those countries are able to secure for themselves an abundance of nuclear power at a reasonable price, and if that power is utilized in accordance with long-term plans for the exploitation of natural resources, this will quickly result in a spectacular increase in world income. In the 'hungry' countries the present levels of production are so low and the unexploited or inadequately exploited resources so great that even a

[1] Article in *Harvard Business Week*, March-April 1955, entitled: 'Can Moscow match us industrially?'

moderate effort—provided it were systematically planned—could bring about a marked improvement in the standard of living and appreciably increase the national wealth. By supplying an abundance of electric power where it is at present lacking, and thereby tending to equalize the distribution of energy resources among the different countries, atomic energy will eventually *even out the great disparities* that at present exist

WORLD PRODUCTION

Percentages of total contributed by the United States, Europe and Asia in 1952, and probable position in 1975 and 2000



between the industrialized and the underdeveloped countries. It will eliminate the gross inequalities in production possibilities and hence in national wealth, and will lead to a better-balanced world economy and a more homogeneous economic and social structure. *The geopolitical map* of the world will take on a new aspect.

It would not be excessive to predict that in twenty years' time the distribution of the world's wealth will have completely changed. If the use of nuclear power has become general by 1965, the Asiatic countries may, by 1980, be producing 25 to 30 per cent of the world's total output of goods and services, instead of 10 per cent as at present, and by the year 2000 about 50 per cent.

The first industrial revolution, based on coal and the steam engine, gave Britain in the first place, and then Europe as a whole, economic and political predominance. The second

revolution, based on electricity and oil, brought the United States, and later the Soviet Union, into the first rank of the Great Powers. The third revolution, which we are now witnessing, based on the immense potentialities of atomic energy, will bring Asia into the foreground of the world scene. After centuries of eclipse, China and India will once again figure prominently in the history of human progress, and play the role for which they are fitted by the traditions of a civilization dating back for thousands of years, and to which they are destined by reason of their immense wealth of manpower and their vast, and as yet largely unexploited, material resources.

On the geopolitical map of the world of the future, certain other regions will figure less prominently. The Middle East, for example, which because of its oil resources is at present the apple of discord among the great powers, will, from about 1965 onwards, progressively cease to be a preoccupation of international policy. On the other hand, regions which, like Latin America and Africa, are rich in natural resources, will rapidly become industrialized, thanks to atomic energy.

Thus, with the growing utilization of atomic energy it will be possible to exploit the resources of the earth in such a manner as to provide sufficient food for its population and to ensure a constant improvement in the standard of living.

If, with a population density of 82 persons per square kilometre, Europe could easily nourish its population much better than it does at present, why should not the world as a whole, with a density of only 19 inhabitants per square kilometre, be able to support a population four to five times larger than at present, and that quite apart from the fact that the raising of the living standard will in the long run affect *birth rates* as well as death rates? Statistics and investigations show that malnutrition is one of the causes of a high birth rate, whereas the rate tends to fall in proportion as the standard of living rises. Parents' sense of responsibility, their desire to give their children a good education, the maintenance of full employment and the development of social security—all characteristics of a well-organized society—are factors which contribute to a

more balanced fecundity than is to be found in countries whose population is undernourished and underemployed.

It may be said, then, that after there has been a certain further expansion of the world's population, it is probable that there will be a *slowing down* of the present rate of population growth, a development which may be considered as characteristic of a society in an advanced and prosperous condition.

Chapter 9

WILL ATOMIC ENERGY OVERTHROW INDUSTRIAL CAPITALISM?

1. THE INFLUENCE OF TECHNOLOGY ON THE PRESENT ECONOMIC STRUCTURE

The student of humanity's evolution through the centuries observes that it is marked by a continuous succession of economic, social and political transformations.

In particular, he will note a constant readjustment of the state's objectives to bring them into line with new economic and social conditions. History points, indeed, to the conclusion that there exists a close interdependence between the economic and social structure and the objectives of the state,[1] for it is apparent that whenever the economic system undergoes a modification, or a new social class becomes predominant, those objectives show a corresponding change. The old concept of 'the public interest' is adjusted to coincide with the interests of the new 'ruling class'. The mercantilist state, the bourgeois state, the capitalist state, the fascist state, the socialist state and the communist state are all phases in the continuous process of economic and social change, these phases corresponding to the successive rise to power of different social classes and being marked by a fresh readjustment of the objectives of the state.

¶ *Transformation of the social conscience*

Parallel with these economic, social and political changes, we note in the course of history a transformation of the *social conscience*. Ideas, philosophic theses and judgments vary according to the epoch, the prevailing economic system and the

[1] See the author's *Planisme et progrès social*, Paris, 1953, p. 11 et seq.

current pattern of social relationships. The doctrines which fashion man's conduct, and thereby affect the course of human evolution, are to a great extent the reflex of economic facts. There is also a constant change in man's mentality and attitude towards life. The man of the twentieth century thinks differently from the man of the nineteenth century. Under the influence of the new currents of philosophic thought, modern man refuses to accept the 'great social evils' as inevitable. He believes, on the contrary, that they must and can be conquered.

Man today is not content with having won his political rights, but intends to use them to secure his economic and social rights as well. His demands are for a greater measure of social justice, a larger and more equitably distributed national income, and a higher standard of living. He no longer regards poverty and inequality as 'natural' conditions. He will not accept the view that economic crises are inevitable, or that private ownership of the principal means of production is 'sacred'. He demands the right to employment and to an income sufficient to cover the essential needs of himself and his family. He believes that full employment, social security and the adequate remuneration of labour and, in general, all the essential conditions of progress and development, come within the framework of the state's responsibilities.

This constant process of transformation has now become more rapid than ever before in history. Methods of production, means of transport and communication, political and social institutions, ideas and systems are evolving at an unprecedented pace. The most important factors in this acceleration are technological progress and the active entry of the masses into economic life.

At all stages in his history, man's capacity in the struggle for existence has been largely determined by the technical aids at his disposal. Technology plays a part in every sphere of human activity, and its progress largely determines the course of economic and social development. For some three thousand years, advances in technology were of a relatively minor nature and, correspondingly, the fundamental economic situation underwent comparatively little change. The intro-

duction of the steam engine, however, marked a great turning point in economic history. Between that event and 1900, the productivity of labour doubled. Since 1900 it has again doubled, thanks to electricity and oil. The appearance of these new sources of energy transformed industrial techniques and greatly accelerated the rate of economic progress in the countries which were the first to make use of them: the economic map of the world took on an entirely new aspect.

The active entry of *the masses* into economic and social life has, as we have said, been the second accelerating factor. The working class, conscious of its strength and of the value of its contribution to economic progress, is insisting on the fuller and more rapid satisfaction of its legitimate demands. The rise in the standard of living creates new and ever more varied needs. The growth in purchasing power calls for a more intensive application of new production techniques and for a more rational utilization of human and material resources.

Atomic energy and the appearance of the *underdeveloped countries* on the international scene will still further hasten the transformation of world society. We shall consider later the importance of these two new factors.

¶ *The geopolitical influence of technology. Marxist theory*

Development of the production process is directly determined by advances in science and technique.[1] Hand tools, the steam engine, machine tools and electricity represent successive important stages in the evolution of production, which in turn plays a primary role in economic and social development. Each phase of the mechanical age has left its imprint on civilization. The industrial revolution of the eighteenth century based on the invention of the steam engine, put an end to feudalism, transformed production methods, manners of

[1] Among works which deal with the question of the relationship between technique and economics, mention may be made of:
Lewis Mumford: *Technics and Civilization*, London, 1947.
Jacques Ellul: *Le technique ou l'enjeu du siècle*, Paris, 1954.
Rencontres Internationales de Genève: *Progrès technique et progrès moral*, 1947.
S. B. Glough: *Grandeur et décadence des civilisations*, Paris, 1954.
André Siegfried: *Aspects du XX^e siècle*, Paris, 1955.
J. D. Bernal: *Science in History*, London, 1954.
J. Forastie: *Le grand espoir du XX^e siècle*, Paris, 1949.

thought and the style of living, and brought the capitalist system into being. The second industrial revolution, which began about 1880, was primarily due to the generalization of the use of electricity: it created large-scale enterprise, led to the rationalization of industry and carried capitalism to its zenith. For nearly two centuries the world has lived under an expanding capitalist system. The state has repeatedly had to modify its objectives, and with every change a new social equilibrium has been established. These changes have always been followed by a growth in production and an improvement in the standard of living—which proves that the changes had become necessary.

It was also technical progress that made it possible for certain countries to attain their economic power. Great Britain achieved supremacy by being the first to exploit intensively the technical inventions of the second half of the eighteenth century. With a certain time-lag, France followed Great Britain's example. Around 1880 these two powers were joined by Germany and the United States, who still further intensified the industrialization process and extended the scope of capitalism by the creation of large industrial trusts and cartels. This was the age of monopolies.

Electricity and oil opened up new possibilities for industry, and enabled the United States to become the dominating economic power of the early years of the twentieth century. After the First World War the Soviet Union, thanks to a social revolution and the accelerated application of new technical methods, very considerably reduced the lead that had been gained by the Western countries. There was thus a new change in the balance of economic power. Europe lost her industrial hegemony and her preponderant position in international finance.

If earlier scientific discoveries exercised so profound an effect on production and on the economic and geopolitical structure of the world, what will be the effect of the generalization of the use of atomic energy? Will it not completely transform the present structure. A century ago Karl Marx said that social relations were closely bound up with productive forces:

'In acquiring new productive forces men change their mode of production; and in changing their mode of production, in changing the way of earning their living, they change all their social relations. The hand-mill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist.'[1]

Marx believed that capitalism was destined eventually to cause the disappearance of private property, which would be succeeded by collective ownership of the means of production or, in other words, by socialism. He did not, however, believe that technique alone could lead to a radical change of system. The transition could only come about, he said, as the result of a 'qualitative change' in capitalism. Will atomic energy, in the function of a new industrial technique, eventually confirm this theory?

2. WILL ATOMIC ENERGY ELIMINATE LARGE-SCALE PRIVATE ENTERPRISE?

Because of its gigantic potentialities and the enormous amount of capital required for its production, atomic energy can only be entrusted to the state or to enterprises directly controlled and financed by the state. From this point of view, the first decision taken by the American Congress in 1949, to the effect that atomic energy research and production must be in the hands of the nation, was absolutely right. On the other hand, the decision of 1954 in favour of 'denationalization' of the atom, and of entrusting the construction of nuclear power plants to private enterprise, is in our opinion not only contrary to the public interest but also calculated to prejudice the real interests of private enterprise itself.

The fact that we are still only in the experimental period means that each successive advance in nuclear science will entail such changes of technique that former processes will rapidly become out of date and existing plants useless. The experts tell us that in the next ten years the major atomic countries will devote every effort to perfecting the working of nuclear power stations by introducing improved types of reactors and more rational operational methods. This con-

[1] Karl Marx: *The Poverty of Philosophy*, p. 92.

tinuous process of experimentation, involving the investment of enormous amounts of capital, cannot be governed solely by normal considerations of profit and loss. Up to 30 June 1955 the United States had already invested about 12,000 million dollars in nuclear development. In the single financial year which ended on 30 June 1954, the American Atomic Energy Commission spent 784 million dollars, including 218 million dollars on atomic weapons. If the figure for the year 1953/54 can be taken as representing a normal annual average, the cost of nuclear research, development and production—apart from atomic armaments—over a period of ten years will amount to some 5,500 million dollars.

Private enterprise could not possibly shoulder a financial change of this magnitude; still less could it support the financial consequences of the rapid introduction of an entirely new nuclear discovery. If controlled thermonuclear fusion becomes a reality within the next ten years, as many experts believe will be the case, nuclear fission will pass into atomic pre-history. What will be the financial effect of this development on those private enterprises which, directly or indirectly, have linked their fate with nuclear fission?

Discussing nuclear development in the United States, the American journal, *Business Week*,[1] sees a close parallel between the reactor industry of today and the automobile industry of fifty years ago. At that period it was the aim of the motor-car manufacturers to evolve a model which would command a steady and profitable sale. Similarly, reactor manufacturers today are seeking the 'reactor of the future'. It is too soon to forecast who will be the Fords, Chryslers or General Motors of the nuclear reactor industry, but, says *Business Week*:

'One guess can be made with some certainty. There are likely to be a number of Auburns, Dorts and Marmons in the field—companies getting in and out of reactor work over the next decade or so, and some of them lucky to take their shirts with them.'

This American journal thus regards the outlook for the early reactor manufacturers as extremely precarious, and

[1] *Business Week*, 7 May, 1955.

here it is a question only of enterprises within the confines of one national economy. There seems, therefore, even more reason to wonder what will be the consequences of this new industrial revolution within the wider framework of a competitive world economy.

We have already remarked upon the hesitancy of private enterprises to embark on the construction of nuclear power stations, unless the state gives them a firm guarantee of a reasonable return on the capital invested. In view of this attitude the Chairman of the U.S. Atomic Energy Commission Admiral Strauss, has felt compelled to state that unless private industry makes an adequate response to the invitation to build nuclear power stations, the American government will itself take the initiative in this sphere.

This lack of enthusiasm on the part of private industrial undertakings largely accounts, as we have already seen, for the fact that the United States is lagging behind other atomic nations in nuclear power development for industrial purposes. Recently there has been evidence of a growing uneasiness in the United States about this situation, and certain sectors of public opinion have been demanding the adoption of a 'crash programme' of atomic development.[1]

¶ *International competition must take place between public organizations*

In an earlier chapter we explained why it is not possible to delay or to echelon the effects of this industrial revolution. The present division of the world into two blocs will accelerate technical progress and will inevitably result in an accentuation of competition.

Immediately the Soviet Union builds reactors and nuclear power stations, and produces fissile materials and radioisotopes for export, atomic competition will have begun. This competition will take place between states, or between enterprises under direct state control. If on the international plane there were competition between, on the one hand, a country in

[1] See *The New York Times*, 17 February 1957. On 10 March 1957 Senator Clinton Anderson expressed the view that the United States was not making sufficient progress in atomic power to keep abreast of world development.

which production was controlled and prices were fixed by the state, and, on the other hand, a country in which production methods and costs were determined by private enterprises, there can be no doubt that the first country would come off best. The governments of capitalist countries will therefore be compelled to keep the administration of atomic industry in their own hands and to fix their prices in accordance with the exigencies of international competition.

In this case, what will become of the private atomic enterprises? They will either have to be subsidized by the state or entirely eliminated. If the state decides to keep them alive by covering their losses, this policy will provide a striking example of the paradoxical situation in which, under the capitalist system, a large private enterprise is able to 'socialize' its losses in times of crisis.

That there is nothing fanciful in the above presentation of this problem would appear to be confirmed by certain actual developments. At the beginning of the Geneva Conference the American Atomic Energy Commission announced its first list of prices for the sale or lease of certain fissile materials. This announcement created some apprehension in Great Britain. Shortly after the conference, an Agence France-Presse dispatch from London said that a race had begun between the United States, Great Britain and the Soviet Union to secure firm contracts for the supply of nuclear power plants. One can imagine how this competition will be intensified when Western Germany, Japan and other countries join in. Competition is likely to be so keen that the producer countries will constantly have to adjust their prices to take account of successive developments in nuclear technique, and the required adjustments may well exceed what could be borne by private enterprise. *The New York Times* has already reported complaints from American firms about the way in which the American government is fixing certain atomic prices. If at the present moment, while the atomic market is still very restricted, private enterprises are already encountering serious difficulties, one may well wonder what their position will be when competition widens and when, in addition, political factors enter into the fixing of prices.

In the light of present conditions, therefore, it would seem that if the so-called capitalist countries are to be in a position to stand up to ever keener competition, they will be compelled to entrust the exploitation of the atom to public organizations.

¶ *The diminishing role of private initiative*

The entry of atomic energy into the economic life of individual countries and into the international market will moreover have serious repercussions on private enterprises. From the moment when atomic energy begins to supply motive power on a large scale, and at a cost which will progressively fall below the cost of power from the conventional sources, the value of the installations for the production of power from these latter sources will gradually diminish. The same will be the case with the plant of those enterprises in which the 'energy' factor weighs heavily in the calculation of production costs.

These repercussions will become even more marked as soon as the manufacture of atomic bombs ceases and science succeeds in harnessing thermonuclear fusion. Some economists assert that the advent of atomic energy will not constitute any particular problem for the economy since, in general, motive power is a relatively minor element in production costs. Such a view fails to take account of the full significance of this new scientific achievement or of the state of the world in which we live. The repercussions on the pattern of industry in each country and in the world as a whole will be such that it will be impossible to assess them merely in terms of price differentiation within the framework of a static economy.

The geopolitical transformation which will be brought about by the generalization of the use of atomic energy will shake the social structure of the so-called capitalist countries to its foundations, the more so as the system of private enterprise is already in the throes of a sufficiently serious crisis. The scope for individual initiative is in fact shrinking in proportion as science and technique progressively co-ordinate all phases of production. Here are André Siegfried's views on this increasing effacement of private initiative:

'It must be admitted that the conditions of modern industrial

production are unfavourable to individual initiative and personal liberty. The artisan epoch, founded on the tool, the simple prolongation of the arm—and of the brain—has been succeeded by the mechanical epoch founded on the machine, which introduced the reign of the engineer. But now, it would seem, we have entered into a new phase in which technique pure and simple is giving way in importance to organization and administration. In this administrative age, in which the complex management of affairs necessitates a prior view of the whole and a deep feeling for the ultimate execution, the big productive unit has become a necessity. The world can no longer advance in extended order; mass-man has replaced the anarchic individual.'[1]

Small and medium-sized industrial enterprises must, in fact, cease to exist unless they are capable of organizing themselves on some collective basis which will enable them to share with the larger enterprises in the advantages of technical progress. M. Gabriel Ardant, 'Commissaire général à la Productivité', in France, appealed on 6 October 1955 to small and medium-sized businesses to 'co-operate in order to survive', stating that they had no alternative but to 'evolve or disappear'.[2] The wave of company mergers recently noticeable in the United States is an indication that the medium-sized firms in that country are realizing the necessity of adapting themselves to the present trend of economic development. The tendency is towards the creation of 'giant companies'. Although the American Department of Justice vetoed the merger, two leading American steel companies, Bethlehem Steel and Youngstown, recently decided to join forces.

Are the operations of these large production units (which, as M. Siegfried remarks, have become a 'necessity') to be dependent on private initiative? Surely the enormous amount of capital investment involved, the impersonal character of the management and the expansion of the administrative function will tend to 'expropriate' the capitalists and entrepreneurs. Is not this that evolution of capitalism which, to quote Joseph

[1] André Siegfried: *The Character of Peoples*, London, 1952, p. 15.

[2] At the congress of the Confédération générale des petites et moyennes entreprises.

Schumpeter, will 'take the life out of property'. Big private enterprises which have to adapt their operations to a short-term market outlook are vulnerable to economic fluctuations, and can have no assurance of a steady development of their activities. Moreover, the present stage of technological progress calls for a radical change in the present structure of productive enterprise—as we shall endeavour to show in the next section of this chapter.

3. AUTOMATION WILL NECESSITATE A MODIFICATION OF THE SYSTEM OF PRIVATE ENTERPRISE

It is not sufficient to master the forces of nature: they must be made to serve man's needs and to improve all those conditions which collectively constitute his standard of living. If the progress of science is not made to fulfil this mission, the fault will lie, not with the scientists, but with those who govern us and with the economic system. If the appearance of a new machine arouses hostility on the part of the worker, this is the fault of those who have failed to assess the consequences of the new technical development and to take appropriate measures in good time, for the purpose of the machine is not to 'put the worker out of a job' but to lighten his labours.

'The greatest practical benefit which all these inventions confer on man' (wrote Albert Einstein) 'I see in the fact that they liberate him from the excessive muscular drudgery that was once indispensable for the preservation of bare existence. Insofar as we may at all claim that slavery has been abolished today, we owe its abolition to the practical consequences of science.'[1]

¶ *From the dream of Aristotle to the electronic brain*

As science gains increasing mastery over nature, man is enabled to do a given amount of work in a shorter time, with a greater output. Machines are not only relieving him of a large amount of muscular exertion but also, in some cases, doing the 'brain work' for him. Aristotle's dream is thus becoming reality:

'If every instrument could, on an order received or even intelligently anticipated, work of its own accord (wrote the Stagirite), like the statues of Daedalus or the tripods of Hephaestus which, the poet tells us, betook themselves unaided to the conclaves of the gods, if shuttles could weave alone, if the plectrum itself could play the cither, then employers would be able to do without workers and masters without slaves.'

[1] A. Einstein: *Out of My Later Years*, London, 1950, p. 135.

Consider the achievements to date in the sphere of *cybernetics*. Factories can now be equipped with machine tools operated entirely automatically and by remote control. 'Electronic brains' are already replacing part of the personnel in numerous professions. One insurance company estimates that the work of 200 employees can be done by a single machine which performs a dozen operations simultaneously, including complicated risk calculations and the working out of agents' commissions. The Secretary of the American Treasury announced on 15 October 1955 that his department would shortly instal an electronic brain that would replace 450 officials and save $2\frac{1}{4}$ million dollars a year. It will do all the book-keeping operations connected with the 350 million cheques drawn annually by the government. A large department store in Chicago has just installed a robot which, at the close of the day's business, prepares an inventory of the 2,500 articles on sale, and automatically makes out replacement orders if the stock of any articles has fallen below the critical level. There are electronic machines which can perform the most complicated calculations at a speed approaching the speed of light. One machine exhibited at the International Congress of the S.I.C.O.B. in Paris in October 1955 can 'read' 16,000 figures a minute. Even this performance, however, can be bettered by using magnetic strips known as 'memories' by means of which it is asserted that 'the machine can "read" the equivalent of fifteen 250-page novels in five minutes'.

At a conference held at Geneva in January 1957, expert statisticians forecast the growing use of electronic machines for compiling census data, for wage and salary accountancy and for book-keeping in general. They believed that the use of these machines might modify the whole concept of the handling of statistical data. It is now expected that electronic

apparatus will be used in compiling the population censuses of 1960, which are to be co-ordinated on a world scale.

¶ *Towards the four-day working week*

What will be the repercussions of automation, the development of which will be accelerated by the utilization of atomic energy? First of all, it will result in a reduction in the number of workers in industry and of clerical employees in the public service and elsewhere. As regards the automobile industry, the American trade unions estimate that with the spread of 'push-button' production, it will not be long before 200,000 workmen will be able to do an amount of work which at present requires 1,000,000 pairs of hands. In the radio-electric industry, automation will lead to a very great reduction in personnel. In October 1955 the American army installed its first automatic 'typist', a machine which can copy a script without mistakes and in triplicate. One of these machines will do the work of 350 typists. What has already been achieved emboldens Mr. Walter Reuther, the American trade union leader, to predict that, thanks to automation, the *four-day working week* will be a reality within the next ten years.

Although, however, automation means fewer employees operating more machines, it calls for an intelligent and trained personnel for the planning and introduction of the automation itself. In an article in *Harper's Magazine*, Mr. Peter F. Drucker, economic adviser to several large American companies, who has made a special study of automation, stressed that 'the central problem of automation is not that of production, but that of organization and planning'.[1] Even for the lower grade occupations, the personnel will have to possess a reasonably good education. According to Mr. Drucker, one large American company which employed a staff of 150,000, would need 7,000 graduates when it was 'automatized', as compared with 300 in the past.

In view of this revolutionary advance in technology and of

[1] See also: Paul Einzig, *The Economic Consequences of Automation*, London, 1956; E. M. Hugh Jones, *Automation in Theory and Practice*, London, 1955; and R. H. MacMillan, *Automation, Friend or Foe?*, London, 1956.

the imminent application of atomic energy to industrial use, the scientific and technical training of personnel becomes an urgent necessity for every country. In the peaceful competition of tomorrow the armies will consist of technicians and engineers. The problem that now presents itself, therefore, is that of making scientific and technical education accessible without delay to a much larger portion of the population. The present 'output' of the educational institutions will not be sufficient to meet the needs created by this new industrial revolution. In a paper presented at the Geneva atomic conference, UNESCO rightly stressed the urgency of drawing up new educational programmes, in order that the rising generation may be rapidly prepared for the exigencies of this new technical age.[1] Both the United States and the Soviet Union are taking active steps to make scientific and technical education and training available to a wider section of the population.

¶ *The danger of 'technological unemployment'*

Mechanization, the extension of automation and, above all, the use of atomic energy will result in a great reduction in the present number of employed personnel, not only in the 'primary' but also in the 'tertiary' industries. The few examples we have already cited are eloquent in this respect. Some authorities foresee that 20 to 30 years from now one-third of the population of the globe, working 4 to 5 hours per week, will suffice for the satisfaction of all humanity's material needs.

How will it be possible to avoid the unemployment that might be expected to result from the present amazing progress of technology? If the solution must be a reduction in working hours, this will create a further problem: that of the use of increased *leisure*. How is this problem to be solved? It is said that this 'empty time' must be filled by 'culture'. Denis de Rougemont writes: 'We are on the eve of an age in which culture will become *the serious business of life*.'[2] Scientific education, vocational training, 'culture', travel, sport, etc., will have to be 'planned' and organized, or we shall be faced with a

[1] Document P/738.
[2] 'L'aventure technique', in the review *Preuves*, October 1955.

situation in which ill-employed leisure results in idleness, demoralization and unhappiness. We have entered an age in which, whether we like it or not, 'planning' will become increasingly necessary as a result of the almost daily advances in science and technique. Quite apart from the repercussions of the generalization of the use of atomic energy, automation in itself presupposes a well ordered and expanding economy, working on the basis of a predictable market for its products. Production must follow a smoothly rising curve; automation and cyclical fluctuations are mutually incompatible. The maintenance of this even rhythm of production will necessitate a study of the probable long-term movement of demand and supply and the drawing up of long-term manufacturing programmes. Apart from a skilled and specially trained personnel, there will be need of a public administration with the ability to plan, organize and co-ordinate industrial activities so as to ensure balanced progress in all sectors of the economy.

Will a state which is still wedded to the principles of 'free enterprise' be capable of coping with these multiple problems? After examining the probable repercussions of automation in the United States, Mr. Drucker wonders whether the present régime can survive the present rapid development of industrial technique. He believes that enterprises will be slow to adopt the new technical methods and adds:

'One thing, however, is certain: the arrival of automation will not be merely a technological revolution of which the automatic factory will be the symbol; *it will bring about a complete modification of the structure and equilibrium of the American economy at all stages of production and distribution.*'[1]

In conclusion, Mr. Drùcker asks whether direct government intervention, which is already accepted in America, will be capable of solving the new and serious problems with which the government will be faced during the next twenty years, particularly as each of these problems will give rise to violent political dispute. Automation holds forth the promise of a better life, says Mr. Walter Reuther, the American trade union chief, provided the fruits of expanding production are

[1] Our italics.

equitably shared out. Otherwise, he adds, the outlook for the world will be one of 'unemployment and distress'.

All these, however, are *pre-atomic* problems. What of the problems that will be raised by the utilization of atomic energy?

4. ATOMIC ENERGY A FACTOR IN THE RAPPROCHEMENT OF CAPITALISM AND COMMUNISM

It follows from what we have just said that:

1. atomic energy will result in a great extension of public enterprise, which will gradually assume a preponderant role in economic activity;
2. the generalization of the use of atomic energy in industry will have repercussions that will seriously threaten the continued existence of large-scale private enterprise;
3. automation will bring about important changes in the system of private enterprise.

It may be expected that the impact of atomic energy will seriously shake the basis of industrial capitalism, and that this new situation will lead to the *nationalization* of the larger production units and to the adoption of a system of *central planning*, the objective of which will be the improvement of living standards.

If this industrial revolution resulted in the diminution, and eventually the elimination, of *large-scale private enterprise*, it would be possible to take Marx's analogy a step further and say: 'The hand-mill gives you society with the feudal lord; the steam-mill, society with the industrial capitalist' . . . and atomic energy has given you the socialist society.

Even if this part of Marxist theory thus proved true, however, we do not believe that this would be the case with that other part which asserts that transition to a new social structure must inevitably involve 'revolution' of a violent nature. In a situation in which, even in the most powerful capitalist countries, there are strong currents of opinion in favour of structural reforms, we believe that the transition to socialism could be effected by *democratic methods*. We believe that at the present juncture the transition could be achieved without any recourse to violence,

if the governing classes, conscious of the way in which technical progress is transforming the economic and social organization of the world, accepted the necessity of adopting 'revolutionary reforms' that took account of the new realities. The workers of all categories are becoming an increasingly powerful political and economic force, and the present conflict between the workers and the 'ruling classes' can only end in favour of the former. It is certain that in the long run nothing can be done contrary to the will of the working class; nor can its legitimate aspirations be ignored. The President of the Italian Republic, Signor Gronchi, on assuming his functions on 12 May 1955, said:

'No real progress can be achieved in the internal life of any nation, or in international relationships, without the consent and support of the world of labour . . . I refer in particular to that mass of workers and to that section of the middle class which universal suffrage has brought to the threshold of the edifice of the state, without however actually allowing them to enter and participate in the political direction of the state.'

The outcome of this conflict—which the atomic age will render still more acute—will determine the whole future course of evolution. If the workers were to unite in support of the programme which the technical, economic and psychological conditions of our time demand, the 'transition' to socialism could be effected democratically, without disorder, without revolution. If, on the other hand, big industry remained blind to the exigencies of the new age; if disunity among the workers made democratic evolution impossible; or if governments, fearful of innovation, failed to adapt their policies to the realities of this new industrial revolution; then events might follow a course that would justify the whole of Marx' prediction.

The future will depend on our capacity to adjust our thinking to fit the new conditions and to free ourselves from the 'old ideas' which, in the words of J. M. Keynes, 'ramify into every corner of our minds'. The following passage from André Siegfried's recent book is worthy of note in this connexion:

'The world is being transformed before our very eyes with lightning rapidity. We know it, we see it; but would it sound paradoxical if I said that we still do not believe it? The intelligence reacts quickly, the understanding slowly. Hence the present crisis. In this age of the light-year and the jet aeroplane, many of us are still living mentally in the days of the stage-coach. But now everything must be changed: our activities, our methods, our relationships, our whole scale of values—in a word, our very civilization itself. Up to yesterday, civilization was determined by culture; from today onwards technology will be the dominant factor. A new age is being born . . .'[1]

¶ *Rapprochement through the 'socialization' of capitalism and the 'democratization' of communism*

Atomic energy can become the connecting link between the two at present hostile systems, gradually bring them closer together, and finally unite them, provided peaceful co-existence, conceived in a spirit of co-operation, forms the basis of international policy in the years that lie immediately ahead. The extension of the system of public enterprise as a result of the economic changes brought about by atomic energy, together with the gradual nationalization of the large units of production, must inevitably lead to the 'socialization' of capitalism.

This trend is a natural continuation of the past evolution of the concept of property. At one time even human beings were 'chattels' in the ownership of other human beings. There was a time when a man could freely decide how his property should be disposed of after his death. Today, the legislator intervenes and increasingly curtails that freedom of decision. Much of what was formerly regarded as just and lawful appears inadmissible today. Many people today hold the view that the large units of production perform a *social function* and should therefore be owned by the community and not by a privileged minority. Today progress depends on the volume of capital investment, on steadily expanding production and on the co-ordination and planning of the nation's economic activities as a whole. Only the state is capable of ensuring the rational fulfilment of these conditions of progress.

The adoption of the policy of 'nationalization of the large units of production' (which would put an end to the often

[1] *Aspects du XX^e siècle*, Paris, 1955, p. 193.

iniquitous influence of trusts and cartels) might eventually induce the communist countries, for their part, to follow a policy of 'democratization'. No longer having reason to fear 'capitalist encirclement', those countries might gradually introduce a greater degree of flexibility into their governmental system. The present structure of the Soviet state is, according to Stalin, indispensable 'for the defence of the conquests of socialism against attacks from outside', and will remain indispensable 'so long as the country is surrounded by capitalist countries and menaced by military aggression from without'.[1] It might, therefore, be logical to expect that, once the danger of 'encirclement' had ceased to exist, the Soviet state would evolve on democratic lines. It is such a development that would make possible a rapprochement between the two blocs.

The necessity for a constant adjustment to new conditions applies, in our opinion, not only to the capitalist countries, but in an equal degree to the communist countries. It now seems clear that since the death of Stalin the 'collective direction' of Soviet affairs has resulted in greater suppleness in the administrative system.[2]

A year before Stalin's death we wrote the following in *Planisme et progrès social* (Paris, October 1953):

'This policy, which aims at the rapprochement of the capitalist and communist countries, is not a romantic idea or a utopian concept. Let us not forget that "capitalism" has lost its orthodox form. Faced with the necessity for social reforms, it is compelled to make certain concessions if it is to be able to find a new equilibrium. Further, "communism"—Soviet communism—has passed beyond the stage of "liquidation" and "stabilization", and has embarked upon the construction of its economic system. It also, like capitalism, is obliged to make certain concessions with a view to a rapprochement, and to follow a policy of peaceful co-existence.'

The course of events appears to be justifying these views.

The 20th Congress of the Soviet Communist Party gave a

[1] J. Stalin: *Questions of Leninism.*
[2] The works of Isaac Deutscher, Henri Shapiro and Lazareff may usefully be consulted on the subject of the evolution of ideas in the Soviet Union since the death of Stalin.

new turn to the internal and external policy of the Soviet Union—a development variously referred to in the west as 'destalinization' and 'desatellization'.

'Destalinization' is an expression of the necessity for an adaptation of the structure of the Soviet régime to present realities. The death of Stalin provided the occasion for a series of reforms for which the Soviet people had long been waiting. The post-Stalin adjustments in administration, economic policy and the conditions of daily existence, accompanied by a tendency towards greater freedom of cultural thought and discussion, were the beginnings of a process of democratization which will gradually become more and more extensive. Whereas Soviet policy was formerly rigid and determined by long-term national objectives, to the detriment of the more immediate needs of the population, it is now beginning to pay much greater attention to these needs and to the aspirations of the individual.

'Desatellization' is a further manifestation of this tendency towards 'democratization' in the communist world; it represents, in effect, a measure of 'liberalization' in the relationship between the Soviet Union and the surrounding communist states. This new line finds its definition in the Soviet government's declaration of 20 October 1956, which states that 'the countries of the great community of socialist nations can only base their mutual relationships on the principles of complete equality, of respect for the territorial integrity, independence and sovereignty of each state, and of non-interference in each other's internal affairs'.

It was on the basis of these new principles that, on 29 November 1956—the eve of the Parliamentary elections—Mr. Gomulka, First Secretary of the Polish Communist Party, formulated Poland's new policy in these terms:

'Only socialist Poland—the people's republic of Poland—can constitute a free, independent and sovereign Poland. Only such a Poland can exist, increase in strength, democratize its relationships, ensure the broad liberties of its people and guarantee it work, peace and the prospect of constantly improving material conditions. There is no room for any other Poland or, in other

words, for a programme different from that proposed by our party.'

This policy, which was submitted to the people at the parliamentary elections of January 1957, traces the new lines along which the various 'peoples' democracies' can henceforth develop. It must be added, however, that from the Soviet side certain 'limits' are set to this 'desatellization'. The process of 'liberalization' must take place gradually, one stage at a time. Recent events in Hungary have demonstrated the impracticability, in the present international situation, of attempting to 'force the pace' of this evolution.

¶ *Were the events in Hungary a set-back for 'democratization'?*

If the bloody events in Hungary in October 1956 are looked at against the present international background (a state of 'cold war' in which the world is divided into two hostile camps, an atmosphere of mutual distrust, and a nuclear and thermonuclear armament race) they can be explained as follows:

Firstly: The policy followed by the Hungarian communist party during the past ten years has not satisfied the aspirations of the Hungarian people. Without taking due account of the conditions existing in the country, the party aimed at the rapid achievement of 'total nationalization'; it adopted a programme of over-rapid industrialization, to the detriment of the immediate interests of the population and, in particular, of the working class. The dissatisfaction of the workers, accentuated by the failure of the government to revise its policy to bring it into line with the realities of the Hungarian situation, found expression in a powerful popular movement which finally developed into open revolt against the men in power.

Secondly: This revolt alarmed the Soviet Union, the more so as the Soviet 'encirclement complex' was already being accentuated by the Suez affair. In these circumstances, seizing the pretext that 'reactionary elements' were seeking to overthrow the 'democratic' régime in Hungary, the Soviet Union used its armed forces to crush the 'counter-revolution'.

The Soviet intervention in Hungary, which has done such damage to the communist cause, which has shaken the faith of

many communists, particularly among the Western intelligentsia, and which has dealt a heavy blow at the ideal of peaceful co-existence, would not have taken place if the international situation had been less strained.[1]

It is that situation—characterized in particular by the endeavours of each 'ideological' bloc and each individual great power to protect or improve its own strategic position by intensifying the development of nuclear weapons—which paralyses the United Nations Organization and makes it incapable of taking effective action to bring about a settlement of the problems which are keeping the world in a state of suspense.

There are some who believe that the events in Hungary must have the effect of retarding the 'democratization' of the Soviet régime and the process of 'liberalization' in the other communist countries. We do not share this view. The trend towards 'democratization' is so strong, and the factors which induce it are so powerful, that it cannot be stopped—and still less reversed. The Soviet Union, conscious of this evolution, appears to be prepared to place its relations with the other communist countries on a new basis. In a declaration of 30 October 1956—that is to say, after the events in Hungary—the Soviet authorities stated that they were ready:

(a) to discuss with 'the governments of the other socialist states' measures to ensure the development of trade exchanges on the principle of 'mutual advantage and equality in economic relations';

(b) to eliminate 'all possibility of violation of the principle of national sovereignty';

(c) to examine 'the question of the necessity for the continued presence of its advisers in the other socialist countries.'

This declaration marks a new trend in Soviet policy—a trend which is accentuated by the increasingly prominent role played by the new China in the communist world. In this context it is of interest to observe how the Chinese-Polish communiqué of

[1] Interviewed by the Paris *L'Express* (22 February 1957), Mr. Aneurin Bevan said: 'It is quite clear, now that events can be seen in somewhat better perspective, that the Russians would never have reacted so violently in Hungary had it not been for the Suez business.'

15 January 1957 defines the relationship between the various communist countries:

'Relations between countries of the socialist camp must be determined by the principles of international proletarianism and founded on a common ideology and common goal; but, at the same time, relations between socialist countries and other sovereign and independent countries must be based on the principles of respect for national sovereignty, non-interference in each other's internal affairs, equality and mutual advantage.'

It must be added, however, that the further progress of this process of evolution by way of 'destalinization' and 'desatellization' will depend to a great extent on the attitude of the west. If Western policy encourages the new trend, 'democratization' in the communist countries will proceed rapidly. If, on the other hand, the West resorts to any measures which might alarm the communist countries, the 'democratization' process will be retarded, and it is not impossible that dangerous complications might ensue.[1]

¶ *Towards a synthesis of public property and private initiative*

If, as the whole world hopes, the future evolution of the international situation is free from dangerous complications, the peaceful utilization of atomic energy will lead sooner or later to a synthesis between the nationalization of the main means of production and the exercise of private initiative, that is to say, to a compromise which would secure the promotion of the public interest and at the same time preserve the liberty of the individual. In the so-called capitalist countries the large productive undertakings would be gradually nationalized, while the medium-sized and small enterprises would continue to function within a planned system of production syndicates or

[1] The French journalist, M. Jean Schwoebel, who visited the Soviet Union in January 1957 as special correspondent of *Le Monde*, emphasizes the necessity for caution on the part of the Western world vis-à-vis the Soviet Union, and adds: 'It (the West) must avoid any attempt to precipitate events, thereby multiplying the difficulties of the Soviet Union. A so-called "policy of firmness" which would not hesitate to return to cold-war methods, would not only not hasten the decomposition of the Soviet régime, but would put stalinism back into the saddle. What is even more serious is the danger that a policy of economic and military pressure which faced the Soviet leaders with insoluble dilemmas, might push them into war. There is a real risk of this today, unless the West shows great prudence.' (*Le Monde*, 6 February 1957.)

co-operatives, or possibly also in the form of 'mixed' enterprises.[1]

In the communist countries, collectivization would gradually become less 'total' and more supple, and part of the production of secondary goods would be left to private enterprise. Small private undertakings would function, within the framework of the general economic plan, on a co-operative basis. The system of 'mixed' enterprises, actually in being in China, could furnish an appropriate organizational model which would make it possible to co-ordinate economic activity as a whole, while at the same time safeguarding individual liberties.

As regards the organization of political life, the plurality of political parties would be permitted, and the parties would function within a system of 'democratic socialism'. In the transition from feudalism to capitalism various parties came into existence, all of which proclaimed the universality of political rights and recognized private property. In the same way it might be assumed that the evolution of communism would result in the formation of several parties which, while professing various nuances of socialist belief, would all base their policy on public ownership of the more important means of production and on respect for human rights, not only in the political but also in the economic and social sphere. This does not mean that this form of social and political organization would acquire a character of permanency. Every system is in continual evolution and is constantly adjusting itself to new conditions. Thus, after the phase of 'democratic socialism', a new form of society would gradually evolve. It seems reasonable to venture the hypothesis that if the rapprochement of the capitalist and Soviet systems could be brought about on the basis of democratic socialism, and if a world organization could be created to direct the exploitation of the immense potentialities of atomic energy with a view to assuring the abundance of goods and services necessary to satisfy the multitudinous needs of mankind, then it is not impossible that a true 'communist' society might emerge in which everybody would participate in national production 'according to his needs'.

[1] According to an article in the American review *Fortune* (July 1956), the 500 largest industrial companies in the United States produce approximately half that country's total industrial output, or the equivalent of about one quarter of the total industrial production of the free world.

Chapter 10

THE ATOM WILL IMPOSE PEACEFUL CO-EXISTENCE

1. IS A THIRD WORLD WAR INEVITABLE?

We have already examined the probable repercussions of atomic energy in the economic and social spheres, and have seen that if this new energy source could be used in a rational manner for the service of humanity, the disequilibrium between the world's population and its resources would disappear and the standard of living, which is at present low, would rise appreciably within a very few years. The vast natural resources which the earth contains, and the powerful technical means which science continually places at man's disposal for their exploitation, justify the belief that prosperity is an attainable goal.

There are, however, a number of questions of capital importance that we must consider. Is the world really moving in the direction of a *détente* which would exclude any idea of war? Will peaceful co-existence smooth out international divergences and bring the two opposing ideological systems closer together?

¶ *The role of war in history*

Throughout history war has always been followed by a marked modification of the social pattern. 'It is by war that nearly all known civilizations have perished', says a French sociologist, M. Gaston Bouthoul, and it is war which has marked 'the entry into history of most new civilizations.'[1]

[1] *Les Guerres: Eléments de polémologie*, Paris, 1951, p. 6.

War is sometimes the outcome of a latent conflict that has assumed a revolutionary character. War and revolution are often intermingled; each can be either the consequence or the cause of the other. 'In the history of the world, and more particularly of modern Europe', writes Elie Halévy, 'all the great convulsions have been marked by wars accompanied by revolutions.'

Man often forgets, however, the deeper significance of war, its nature and its purposes. He forgets that war produces psychological changes and accelerates the birth of a new order of society. It is appropriate at this point, also, to recall some casualty figures for the two world wars. Between 1914 and 1918, 10.8 million men were killed; between 1939 and 1945, 52 million people perished, 25 million of whom were civilians. At the battle of the Marne in 1914 the deathroll was 320,000; at Stalingrad in 1942-3 it was $1\frac{1}{4}$ million, of whom 420,000 were Germans. These figures relate only to the killed. It is impossible to give statistics for the other victims, or for the immense amount of material destruction caused by these two wars.

But must war continue to be regarded as an inescapable fatality? Speaking in 1919, on the occasion of the first anniversary of the Third International, Lenin predicted that the First World War would be followed by other wars. 'The whole world sees', he said, 'that a new war of the same kind is inevitable if the imperialists and the bourgeoisie remain in power.'

Today the world is divided into two opposing blocs. Is it inevitable that these two blocs will sooner or later be involved in merciless war, or do the immense achievements of science and technology exclude such an eventuality?

Stalin did not regard war between the two 'camps' as inevitable. Shortly before his death he wrote:[1]

'It is said that the contradictions between capitalism and socialism are stronger than those between the capitalist countries. Theoretically, of course, this is true. It is not only true today: it was true also before the Second World War. The leaders of the capitalist countries understood this more or less.

[1] See his last essay: 'The Economic Problems of Socialism in the U.S.S.R.', 1953.

And yet the Second World War did not begin as a war against the U.S.S.R., but as a war between capitalist countries.'

While adhering to the theory of the 'inevitability of wars between capitalist countries', Stalin stressed that 'war between the two blocs is not inevitable, because the U.S.S.R. is powerful and has no aggressive designs.' In his address to the 20th Congress of the Soviet Communist Party, Khrushchev expressed the following more realistic view:

'War is not only an economic phenomenon. Whether there is to be a war or not depends in large measure on the correlation of class, political forces, the degree of organization and the awareness and determination of the people . . . Now there is a world camp of socialism, which has become a mighty force. In this camp the peace forces find not only the moral but also the material means to prevent aggression.'

There are many, however, who believe that a conflict between the two ideological systems that now divide the world is inevitable in the long run for, they say, the two systems are fundamentally irreconcilable and, what is more, communism openly proclaims that its aim is to secure universal acceptance of its principles.

¶ *Total war inconceivable in the atomic age*

Whatever may be the merits of these arguments, there is one new factor, atomic energy, which upsets all previous theorizing and excludes all idea of another total war. As the Prime Minister of India, Mr. Nehru, has said: 'We have reached a stage when war brings no advantage even to the victor, for war would be a measureless disaster'; he added: 'leaving aside all other considerations, war has become an inconceivable eventuality in the atomic age.' General Gruenther, formerly Supreme Commander of the Allied Forces in Europe, has said on several occasions that in a third world war there would be no winner.

The more the destructive power of the new weapons increases, the more widespread does this view become. In his *Report on the Atom,* Gordon Dean, former Chairman of the U.S. Atomic Energy Commission, wrote these words:[1]

[1] *Report on the Atom,* 1954, p. 278.

'Wars and threats of wars have been a part of man's life all through history. Although many have tried, no one has yet solved the problem of war. But now the atomic age has introduced a new factor that must be taken into the calculations. Whereas before the problem was simply one of war or peace, it is now one of oblivion or peace. With a question like this, it is hard to imagine any answer except peace. Yet man, even in the atomic age, has not chosen peace. He also has not chosen oblivion, and he seems to think he can go on for ever without deciding upon one or the other. Maybe he can, but the risks are enormous.'

When Mr. Dean wrote his book in 1953 he had no conception of what was to be the subsequent spectacular progress of thermonuclear physics. The results of the hydrogen bomb test at Eniwetok in March 1954 were 'incredible', said Mr. Wilson, the American Minister of Defence. Shortly after the explosion of this bomb, the American atomic scientist, D. A. H. Compton, a Nobel Prize winner, who had played an outstanding part in the research which made possible the manufacture of atomic bombs, gave this grim forecast of what a nuclear war would be like:

'A war in which hydrogen bombs were used would be so destructive that even the victorious country itself would be turned into a chaotic slaughter-house and would probably find itself in a worse situation than if it had negotiated a peace on terms equivalent to capitulation.'

Between the explosion of the first two atom bombs at Hiroshima and Nagasaki, on 6 and 9 August 1945, and the first thermonuclear bomb tests, astounding progress had been made in the development of nuclear weapons. Those atom bombs exploded with a force equivalent to that produced by the detonation of about 20,000 tons of T.N.T.: the explosive power of the first hydrogen bomb was estimated to be from one to two thousand times greater.

Let us quote a few figures to give some idea of the destructive power of a thermonuclear bomb. It is calculated that 130 of them would be enough to destroy a quarter of the population of the United States and a quarter of that country's industry.

Eighteen of the bombs could wipe out eighteen industrial centres with their combined population of about 30 million. The British military expert, Liddell Hart, estimates that 5 hydrogen bombs would suffice to destroy the vital centres in Great Britain, while 10 could annihilate the principal industrial conglomerations which contain half the country's total population. Jules Moch calculates that 15 hydrogen bombs could paralyse all the vital centres in France.

What is equally disturbing is to be told by an eminent American atomic physicist (Dr. Ralph E. Lapp) that 'the manufacture of these new super-bombs is relatively easy and cheap.' Dr. Lapp goes on to say:

'Half a kilogram of ordinary uranium costs only eighteen dollars. Used in a super-bomb, this amount of uranium can be made to release explosive energy—at a cost of about half a cent—equivalent to a ton of T.N.T. . . . It is already possible to contemplate the production of a bomb with the same destructive power as one thousand million tons of T.N.T. . . . In the event of nuclear war, use would almost inevitably be made of super-bombs. Immense radioactive clouds would be formed which would cover vast regions with a deadly mantle. This would mean the destruction of the vital centres of the community. It is essential, therefore, that everyone should be fully aware of the danger which threatens. To try to keep these stark facts secret would be like watching a blind man walk towards a precipice without warning him of the danger ahead.'[1]

In such a situation, do people really exist who can envisage the unleashing of atomic war? A new world war would mean the end of civilization. Only 'man's folly', to use Jules Moch's expression, could bring about such a calamity. Will wisdom prevail? Will the scientists and enlightened civilian opinion succeed in convincing the military authorities that they are playing a terribly dangerous game?

The belief that a new world war was unthinkable in the atomic age was strengthened by the fact that an equilibrium of nuclear strength was tending to become established between

[1] Translated from an article: 'Le mystère de la "superbombe",' published in the review *Preuves*, Paris, October 1955, p. 36.

the two blocs. The use of atomic and thermonuclear weapons would, it was hoped, become practically impossible once the two blocs were more or less equally armed with them. In a speech in the House of Commons on 1 March 1955, Sir Winston Churchill outlined the British policy of 'defence through deterrents'. He assumed that within three or four years the Soviet Union might have reached a stage, not of nuclear parity with the United States and Britain, but of what was called 'saturation', a term which he defined as 'the point where, although one power is stronger than the other—perhaps much stronger—both were capable of inflicting crippling or quasi-mortal injury on the other with what they had got.'

This trend towards equilibrium of nuclear strength was the real cause of the international *détente* which led to the Conference of the Big Four and to the subsequent International Conference on the Peaceful Uses of Atomic Energy.

¶ *Guided missiles. Towards the 'ultimate weapon'—the ballistic missile*

Unfortunately, however, this equilibrium is a fluid concept that is constantly being modified by the progress of nuclear science and technique, and herein lies the present menace to the peace of the world. The armaments race in which the United States and the Soviet Union are engaged is without limit and without end. Each power is devoting every effort to discover the 'ultimate weapon'—a weapon so powerful that it will, they believe, make global war impossible by preventing aggression.

But what is this 'ultimate weapon' to be? Yesterday it was the atom bomb; today it is the guided missile with a thermonuclear war-head; tomorrow it will be something still more devastating.

According to American experts the progress achieved in guided missile development in the last year has been 'formidable'. It is a question of a whole brood of 'intermediate-range' and 'intercontinental' devices, bearing such names as Snark, Navaho, Redstone, Jupiter, Atlas, Titan, Thor, Polaris, etc. Most important of all, however, is the so-called ballistic missile,

which it is thought may prove to be the 'ultimate weapon'—the weapon par excellence of 'push-button warfare'. This is a two or three stage rocket, nearly 100 feet long, weighing about 100 tons. In its ascent it develops a speed of some 8,000 miles an hour and reaches a height of about 900 miles. It has a range of about 5,000 miles and completes its trajectory at a meteoric speed of something over 12,000 miles an hour. Its conical nose will contain a thermonuclear charge, the destructive power of which beggars the imagination. It is calculated that the explosion at ground level of a dozen of these missiles would suffice to annihilate the greater part of the population of the United States or of the Soviet Union.

These new nuclear devices will revolutionize the art of warfare: tactics, strategy and the whole military structure will change. It has been predicted that, so far as marine warfare is concerned, the present conventional naval artillery will become so much scrap-iron. The navy will have to take the place of land bases, which will be too vulnerable to attack by ballistic missiles. The submarine would have great advantages as a launching platform for these missiles.

It is on the perfecting of this 'ultimate weapon' that the United States and the Soviet Union are engaged in a race against time. The outcome of a 'push-button war' will be decided, says the American General Le May, by the relative strengths of the two sides on the day the war begins. Are we conscious of the incalculable dangers inherent in this race to be the first to possess 'the ultimate weapon'? Is there still need to repeat that a war fought with such weapons would end in the annihilation of the human race? There is no defence or protection against these latest diabolical devices. Speaking in the House of Representatives at Washington in February 1957, Mr. Peterson, head of the American civil defence, said: 'All the plans prepared by our government for the protection and evacuation of the population will become worthless once this *ultimate weapon* has been perfected.'

There is no lack of authoritative declarations on the part of either the United States or the Soviet Union as to their resolve to achieve at least equality in the development of guided

nuclear missiles. Frequent allusions were made by Soviet leaders between July 1956 and March 1957 to 'projectiles with a thermonuclear warhead which can reach any point on the globe'. In its issue of 23 January 1957 *Pravda* wrote: 'The United States no longer possesses the monopoly of atomic weapons, and still less of long-distance guided missiles, in which domain indeed it may be said that the United States is behindhand.'

The fear of being outstripped by the Soviet Union is causing the Americans to undertake a series of investigations (Symington report, Killian report, etc.) and to embark upon a 'crash programme' of nuclear armament, involving a vast amount of expenditure.[1]

¶ *No war without suicide*

If global nuclear war would be suicidal, it should surely follow that war today in any form becomes unthinkable. A 'limited war' of the conventional type leads inevitably to an impasse, as was the case in Korea, for the risk of seeing it degenerate into a nuclear war prevents both sides from overstepping certain limits. Nations will have to recognize that henceforth, as the Military Correspondent of *The Times* wrote on 8 February 1957, 'aggression under the nuclear shadow is not worth while'.

Is there, however, any basis for the belief that the 'strategy of intimidation', which is the form at present assumed by the cold war, is capable of ensuring peace? Even though it may have cut short the Suez conflict and exercised a moderating influence on developments in Hungary, this does not mean that mutual fear of catastrophe will always prove a factor of wisdom sufficient to hold back adversaries who find themselves on the brink of a suicidal war. The risk is such that one dares neither bluff nor call the opponent's bluff. A policy of intimidation creates a climate of mutual mistrust and fear in which we may one day find ourselves plunged into catastrophe through a

[1] According to an article by a French journalist, M. M. Bosquet (see *L'Express*, Paris, 1 March 1957), seventeen of the largest American industrial enterprises, with their thousands of engineers and technicians, are engaged on research and priority orders for the 'crash programme'.

simple misunderstanding, and it might be impossible—and would certainly be pointless—to determine afterwards who started the war. Technical experts have envisaged the possibility that an innocent meteor might be taken for an intercontinental missile and that a chain reaction of reprisals and counter-reprisals might ensue. In a situation so tense, anything indeed seems possible.

Further, the military bases of each of the two opposing blocs are so numerous that, whichever of the two commenced hostilities, it would be impossible to destroy all the adversary's bases before retaliation began. To quote Professor P. M. S. Blackett:

'I believe that it would prove technically impossible to implement the policy of destroying Soviet atomic air bases in the first few hours of war. Nor do I think it possible for the U.S.S.R. to destroy all the main Western atomic bases at the outset of a war.'[1]

It is this impossibility which in fact makes war itself impossible. Professor Blackett describes what would happen if this theory were not correct:

'However, suppose that I am wrong and that such an operation is a technically possible one for both sides. Then we get the psychological situation of a duel. The one who strikes first wins; the one who fails to strike first is destroyed. In order not to be destroyed, the West would have to strike first—that is, the West would have to wage what would amount to preventive war. It is, however, almost an article of faith in the West that this cannot be done! Sentiment apart, a loose federation of states such as N.A.T.O. is not likely to be good at this type of strategy, which needs strong nerves and quick decisions.'

We can therefore only emphasize once more that co-existence is a 'necessity'. An American expert, Mr. James E. King, Jr., of the Johns Hopkins University, New York, after stating, in a well documented study, that 'total nuclear war is an imminent and deadly peril to all mankind', arrives at this conclusion:[2]

'We and the Communists are forced to collaborate in the

[1] *Atomic Weapons and East-West Relations*, 1956, p. 60 et seq.
[2] 'Nuclear Plenty and Limited War', in *Foreign Affairs*, January 1957, p. 254.

search for an effective limit to war, regardless of other differences. . . . If they must recognize that conventional force cannot be used without limit, we must abandon our preference for crusades, our feeling that wars are only justified if they end in total victory over a hated enemy, that limited wars are "phony".'

What is urgently essential, therefore, if we wish to avoid the supreme catastrophe, is to take effective steps to give international policy a new orientation which takes account of the 'categorical imperatives' of the atomic age.[1] This problem—the most serious with which mankind has yet been confronted—will be considered in the following sections of this chapter.

2. PEACEFUL CO-EXISTENCE A NECESSITY OF THE ATOMIC AGE

As the most eminent scientists and experts have emphasized, war which has reached the 'push-button' stage means collective suicide for the whole of humanity. If this be true—and no one has yet ventured to contest it—we can only repeat that another war must be regarded as an unthinkable eventuality. The Suez affair and the recent events in Hungary have proved that the menace of the hydrogen bomb and the intercontinental missile has paralysed the idea of recourse to war.

There remains, therefore, no other alternative than 'peaceful co-existence'. It is an imperative necessity for the two blocs and for the world as a whole. As early as 8 June 1954—long before the first intercontinental missile had been made—Sir Winston Churchill, addressing a gathering of the English-Speaking Union, used these words:

'It is the duty and also the interest of the communist and free worlds that they should live in peace together and strive untiringly to remove or outlive their differences.'

The same view has been expressed by Soviet leaders. In the report submitted by Khrushchev to the 20th Congress of the Soviet Communist Party on 14 February 1956, he said:

'In present-day conditions there is no other way out. Indeed,

[1] See an article by the author in *Le Monde diplomatique*, March 1957, under the title: 'L'avènement de l'ère atomique exige de nouvelles formules politiques'.

there are only two ways; either peaceful co-existence or the most destructive war in history. There is no third way.'

¶ *The Soviet conception of 'co-existence'*

There are many, however, who view the policy of peaceful co-existence with mistrust. They regard it as nothing more than a 'Trojan horse', or a 'prolonged respite' from which the Soviet Union alone stands to benefit. They maintain that the communist leaders, notwithstanding their peace propaganda and 'campaigns of smiles', are not for one moment losing sight of their ultimate goal, which is the triumph of communism throughout the world. They believe, further, that the communists will take every possible tactical and strategic advantage of the period of peaceful co-existence in order to attain that goal.[1] They point out the significance of such events as the Soviet intervention in Hungary in October 1956.

This point of view is not, indeed, entirely without foundation. Marxist-Leninist philosophy postulates the inevitable victory of communism through the collapse of capitalism. The Soviet leaders do not dissimulate their faith in this doctrine. 'We are all for co-existence,' said Khrushchev, 'but also for the building up of communism.' On the other hand, the Marxists emphasize that they do not seek to convert people to communism by force, and they quote in this context Stalin's phrase: 'The idea of exporting revolution is a stupidity'. As further proof that they regard co-existence not as a tactical manoeuvre but as a fundamental principle of Soviet policy they stress the fact that they have supported the idea of peaceful co-existence 'with the same perseverance in the past, ever since the first years of the Soviet régime'.

On various occasions representatives of Soviet science, basing their arguments for the most part on the teachings of Lenin, have explained why the Soviet Union believes in peaceful co-existence between capitalism and socialism. In an article in the review *Kommunist*—the doctrinal organ of the Communist

[1] On the subject of the possibility of 'peaceful co-existence' see a series of articles by Professor Jacques Freymond, published in *La Gazette de Lausanne*, December/January, 1954-5.

Party—Leontyev gave the following reasons for this belief:

(a) the possibility of co-existence is proved by the fact that it has already been a reality for 37 years;
(b) the progressive forces of the world know that the fall of capitalism is inevitable in the long run, even without war;
(c) the countries of the Soviet bloc do not fear competition with the capitalist world in conditions of peace;
(d) there is increasing recognition in the capitalist countries of the fact that a third world war would inevitably end in the utter collapse of capitalism.

In an analysis of the difference between capitalism and socialism, the Soviet economist, Eugene Varga, states that there is 'no reason why these two systems should not co-exist peacefully for a long time to come, notwithstanding their basic doctrinal differences.'[1] The Soviet leaders believe that economic competition on the international plane will demonstrate the superiority of the communist system, which is destined to triumph over the capitalist system in the end.

In his report to the 20th Congress of the Soviet Communist Party, Khrushchev puts the rhetorical question: 'Now if the Soviet Union is fighting for communism, how can there be any peaceful co-existence with it?' He then proceeds to give the answer:

'When we say that the socialist system will win in the competition between the two systems—the capitalist and the socialist systems—this by no means signifies that its victory will be achieved through armed interference by the socialist countries in the internal affairs of the capitalist countries. Our certainty of the victory of communism is based on the fact that the socialist mode of production possesses decisive advantages over the capitalist mode of production.'

This then is the form of co-existence that is offered to us today. If we accept it we must do so with our eyes open to all its implications: there must be no 'co-existence in fear', no 'co-existence in misunderstanding', but, in the words of Pope

[1] 'De la coexistence pacifique', in *Les Temps Nouveaux*, No. 41, Paris, 1954.

Pius XII, a *'co-existence in truth'*. If after examining the arguments for and against it we come to the conclusion that a policy of co-existence is not merely a necessity, but the only possible way of dispelling the menace that hangs over the future, this policy must be our aim. It is certain that it will not find universal acceptance, particularly with those whose political standpoint is diametrically opposed to the communist ideology.

But must the problem be regarded from this standpoint? What alternative is there to 'peaceful co-existence'—except war? Such a war—which would certainly be a nuclear war, with both sides in possession of weapons of mass destruction—might well mean the extermination of the greater part of the human race. If the West had a monopoly of nuclear weapons, war might be envisaged as a means of 'eliminating the communist danger'. A few hydrogen bombs or guided missiles might suffice to cripple Soviet power. But the Soviet Union also possesses the atomic and the hydrogen bomb and, according to some American experts, appears to be in the lead in the development of the ballistic missile, at present regarded as 'the ultimate weapon'. Thus, a new situation has arisen which enjoins prudence on the part of those who believe that the problem of the conflict of ideologies could only be solved by having a 'showdown'. On the other hand, is there not a real risk that actions designed to intimidate the communist countries would, given the present 'insoluble contradictions', force those countries into war? As an American senator, Mr. Jackson, has said: if tomorrow the Russians showed the Western military attachés a rocket with a range of 1,500 miles, and if a few days later Marshal Bulganin invited the Western foreign ministers to a conference and advised them to adopt a policy of neutrality, what could Western Europe do? 'It is highly probable', concluded Senator Jackson, 'that our allies would be forced to comply.'

Naturally, such a supposition is improbable, for the Russians are equally afraid of nuclear war, knowing full well that it would mean annihilation for them also. An attack by either side would be followed by instantaneous reprisals. 'The atomic bomb menaces the whole of humanity,' said Mr. Shepilov, the

Soviet Minister for Foreign Affairs, speaking in February 1957 at the 6th Session of the Supreme Soviet of the U.S.S.R.[1]

It must be added, however, that there is co-existence and co-existence. A distinction must be made between 'static co-existence' and 'active and constructive co-existence'. The first is practically synonymous with 'cold war': it not only solves no problems, but it holds within itself, as we shall shortly show, alarming menaces for the peace of the world.

3. THE DANGERS OF 'STATIC CO-EXISTENCE'

The 'static' form of co-existence which has been a feature of the last few years is dominated by the spirit of mistrust between the two blocs into which the world is divided. In these conditions it cannot conduce effectively either to international co-operation or to economic development, particularly development of the economically backward countries; nor can it, in the long run, avoid economic crisis or safeguard the peace of the world.

¶ *Resumption of the cold war*

The easing of international tension which manifested itself in the course of 1955 and which, with the conference of the Big Four and the atomic conference at Geneva, gave rise to a wave of optimism, unfortunately did not last for long. The events in Hungary and Egypt in the latter part of 1956, as well as a number of unresolved conflicts, such as those over Algeria and Cyprus, have dealt a heavy blow at the idea of peaceful co-existence and contributed to the return of the cold war. The international situation is once more tense and humanity is living under a Damocles' sword—the hydrogen bomb and the thermonuclear inter-continental missile.

Hostile pronouncements from both sides add to this international tension and to the world's anxiety. Here are several statements which reflect attitudes that are not calculated to ease the strain or to foster international co-operation. Let us

[1] This statement indicates that the Soviet leaders now admit that in a nuclear war annihilation would not be 'unilateral'.

begin with the United States. In his State of the Union Message, read before a joint session of the United States Congress on 10 January 1957, President Eisenhower said:

'The existence of a strongly armed imperialistic dictatorship poses a continuing threat to the free world's, and thus to our own nation's, security and peace . . . Our survival in today's world requires modern, adequate, dependable military strength . . . Our security force is the most powerful in our peacetime history. It can punish heavily any enemy who undertakes to attack us. It is a major deterrent to war.

'In the main, today's expressions of nationalism are, in spirit, echoes of our forefathers' struggle for independence. This Republic cannot be aloof to these events heralding a new epoch in the affairs of mankind. Our pledged word, our enlightened self-interest, our character as a nation commit us to a high role in world affairs: a role of vigorous leadership, ready strength, sympathetic understanding.'

A few days earlier, on 5 January 1957, the American programme for the Middle East, now known as the 'Eisenhower doctrine', was laid before Congress. The 'Eisenhower doctrine' contemplates American co-operation with and assistance to countries in the Middle East 'in the development of economic strengths dedicated to the maintenance of national independence'. Such co-operation and assistance would include 'the employment of the armed forces of the United States to secure and protect the territorial integrity and political independence of such nations, requesting such aid, against overt armed aggression from *any nation controlled by international communism.*'

On the Soviet side there has been a marked stiffening of attitude. Soviet leaders have on a number of occasions denounced American policy, the 'Eisenhower doctrine' and Western policy generally. In a New Year speech, Mr. Khrushchev, who a year earlier had condemned the excesses of Stalinism, said:

'When it is a question of fighting imperialism, we are all Stalinists.'

On 19 January 1957, at a reception in honour of a Bulgarian

delegation, Khrushchev again defended the Soviet intervention in Hungary, adding:

'The attempt is being made to divide and disarm us, and we must be on our guard. To those who attack us we will reply with still stronger blows. Soviet policy is not a short-term policy; we must help each small country of the socialist camp and thereby strengthen the socialist camp as a whole.'

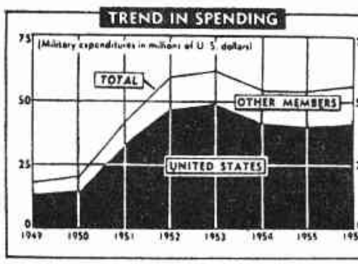
On 23 January 1957 the Soviet TASS agency published a warning to the countries concerned against permitting 'the establishment in Western Europe, the Middle East and the Far East of American units armed with atomic weapons'. The existence of such military bases would, the TASS statement continued, 'have the most serious consequences for those regions.' In addition, Soviet spokesmen have violently attacked 'the Eisenhower doctrine', which they describe as sabre-rattling 'on the brink of war'. The Defence Minister, Marshal Zhukov, who on the occasion of the 20th Congress of the Soviet Communist Party had declared that the next war would be 'atomic, bacteriological and chemical', said on 19 March 1957 that 'in organizing their military bases in Europe and other parts of the world and in supplying certain capitalist countries with atomic weapons, the American imperialists obviously calculate that in case of a war in Europe or Asia they will be able, as formerly, to sit it out over the ocean and avoid destructive and deadly blows. Such calculations,' added Marshal Zhukov, 'are only too naive, of course. At present there is no place in the world where the aggressor could find shelter.'

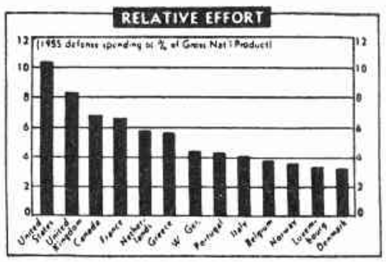
In the face of these declarations by leaders of the two blocs, the intensification of the armament race, and the creation of a bellicose atmosphere, we may well wonder whether we are not heading for a third world war. Anxiety is rendered all the more acute by the fact that the state of 'cold war' has repercussions which are not merely dangerous but might one day prove irremediable.

¶ *An armament race without limits*

The first of these repercussions is the constant intensification of

the atomic and thermonuclear armament race. Since 1950 nearly all countries have been spending large sums on armaments, and in the United States and the Soviet Union expenditure for this purpose has been enormous. The United States budget for 1957–8 contemplates expenditure totalling $72,000 million, of which no less than $38,000 million (or 53 per cent of the budget total) is for rearmament, and this sum does not include the allocations for foreign military assistance, stockpiling or the Atomic Energy Commission. In this context the following two diagrams relating to military expenditure by the N.A.T.O. powers are also worthy of note:[1]





The budget of the U.S.S.R. for 1957 shows overall expenditure at 603,000 million roubles, of which 96,700 million roubles ($24,175 million), or 16 per cent, is for armaments.

The financial burden imposed by rearmament is now greatly added to by the race to be first with 'the ultimate weapon'. This competition, apart from the great risks it involves to peace, is extremely costly. The sum earmarked for missile development and research on new weapons in the American budget for the fiscal year 1957–8 has been estimated at something in the neighbourhood of $6,000 million.[2]

Apart from the risk of war which, we must repeat, the world is running every day, the continuation of rearmament has a number of serious repercussions, and in particular:

(a) the menace of inflation;

[1] Reproduced from *The New York Times* of 3 March 1957.
[2] See *The Economist*, 26 January 1957, p. 285.

(b) the risk of an economic crisis; and
(c) the retarding of economic development in the underdeveloped countries.

Although the communist countries may manage, thanks to a rigid 'dirigisme', to neutralize inflationary pressures, the same is not the case with the Western countries. Experience has shown that rearmament financed by expanding production—as has so far been the case in the United States—does not set up heavy inflationary pressures. Today, however, inflation is becoming a major preoccupation of both government and business circles in the United States. There are many Americans who believe that inflation is now a serious menace to the nation. It is curious to note that even in military quarters some alarm is beginning to be felt at the fantastic cost of rearmament. Speaking at a meeting of the Navy League in Washington on 1 March 1957, two American admirals, Admiral John E. Clark, director of the Navy's Guided Missiles Division, and Rear Admiral Hyman G. Rickover, chief of the Naval Reactors Branch of the Atomic Energy Commission, expressed the opinion that the excessively high cost of manufacturing missiles was 'threatening the security of the nation'. Admiral Clark 'warned that the astronomical costs of outfitting the United States fighting forces with missiles must be brought down'.[1]

It would moreover be dangerous to believe that the risk of war could be eliminated by a great increase in military expenditure. Mr. Allan Matthews, a geologist and resource specialist who has served on the staffs of the U.S. Bureau of Mines, the President's Materials Policy Commission and the National Security Resources Board, recently wrote an article entitled 'The Cost of Preparedness and Risk of War' in which he gives the results of calculations of what it would cost to reduce the future 'big risk' of America's losing a full-scale war to a 'medium risk', and then to lower a 'medium risk' to a 'little risk'. Mr. Matthews' article contains the following instructive, if disturbing, table:[2]

[1] See *The New York Times*, 2 March 1957.
[2] *Bulletin of the Atomic Scientists*, February 1957, p. 51.

CALCULATED RISKS

Decision in 1957 to Determine Situation in late 1959

Risk of losing a Full-Scale War	*Preparedness Level of Democracies*	*Estimated Cost to U.S. of Preparedness for* 1959
Big	Below Soviet bloc.	$40 billion annually in 1957-59 (same as in 1956).
Medium	One-third greater than Soviet bloc in material. Undependable unity.	$61 billion annually in 1957-59 ($21 billion more than in 1956).
Little	One-third greater than Soviet bloc in material. Dependable unity.	$61 billion annually in 1957-59. Federal union of democracies. Compensation to underdeveloped countries of $7 billion annually for special privileges maintained by democracies.

According to these calculations, in order to lower the big risk (the risk of losing a full-scale war) to a medium risk—which presupposes the raising of the Western bloc strength to a level one-third greater than the communist strength—the United States would have to increase its military expenditure by 50 per cent. Thus, as compared with an expenditure of $40,000 million in 1956, $61,000 million would have to be expended annually in 1957–9. To reduce the degree of risk from 'medium' to 'little', the same level of expenditure ($61,000 million per annum) would suffice, subject to two conditions:

(a) conversion of the present 'undependable' alliance of the Western democracies into a 'dependable' federal union;
(b) allocation to underdeveloped countries of financial aid to a total of $7,000 million per annum.

Would such a programme be realizable? If so, whither would it lead us? The federal union, which according to the author of this plan would involve the creation of a supranational authority, scarcely seems feasible when one notes how great are the difficulties at present being encountered in the endeavour to create some measure of union in Western Europe.

And even apart from the obvious fact that the other side will make every effort to ensure that it is not outdistanced, is it possible to increase military expenditure by as much as $21 or $28 thousand million per annum? Would not an economy whose military charges absorbed about 18 per cent of the national product be heading for bankruptcy? Those who deny that this is the case are suffering under a dangerous delusion. If the atomic and thermonuclear armament race absorbs each year so large a proportion of the national product and the economy becomes increasingly militarized, this can only be at the cost of a lowering of the standard of living. This in turn will mean a general reduction in consumption, and it will not be long before this has serious repercussions throughout the economy, so much so that an economic crisis will be inevitable.[1]

¶ *Repercussions on the underdeveloped countries*

Let us now consider the outlook for the underdeveloped countries. The absorption by rearmament of a large part of the national income of the industrialized countries reduces the amount of free capital that could otherwise be utilized for the benefit of the underdeveloped regions. These are unable to procure the means which would enable them to exploit their natural resources and to banish poverty and want. Thus, rearmament is indirectly conducing to the spread of communism.

The chances of communist infiltration are greatest in those countries where, through the apathy or ineptitude of governments, the economic and social situation deteriorates instead of improving; where social injustice increases instead of diminishing; where peoples who aspire to independence are condemned to continue to live under foreign domination.

[1] In an interview with a representative of the *U.S. News & World Report*, on 28 February 1957, the Secretary of the United States Treasury, Mr. George M. Humphrey, said: 'A depression will come if, over a period of time, we keep on spending nearly 50 billion dollars a year in preparation for war, which contributes comparatively little to new capital and making future jobs.'

Wherever these conditions exist, revolutionary movements develop, civil wars break out and an atmosphere favourable to the propagation of communism is created.

In his report for the year 1954, the Director-General of the International Labour Organization wrote: 'Social discontent and impatience for social progress in our world today are a ready occasion for political agitation and are often quick to become a cause of civil unrest'. Tibor Mende, who has spent much time in Asiatic countries and studied on the spot the problems with which they are confronted, writes:

'It is not only against aggression from without that the countries of South-East Asia must today be defended, but above all against individuals, methods and systems which leave the masses no alternative but to turn to communism for the realization of their aspirations. It is a defence which can only be assured by means of reforms, economic aid, supplies of foodstuffs, better organization and a more equitable distribution of national income.'

If the possibility of economic and social development is not assured, concludes M. Mende, South-East Asia will succumb to the internal communist menace without there being any question of 'invasion' by the communist powers.[1]

¶ *The repetition of former errors*

What are the western powers doing in the face of this expansion of communism?

On 9 April 1952 Mr. Harry Truman, then President of the United States, said that one of the tasks of the United Nations must be to foster the economic development of the backward countries. He added:

'If we fail to do this job we will never have world peace. We cannot survive as an island of prosperity in a sea of human misery.'

In October 1952, General Eisenhower also stressed the urgency of dealing with the problem of the underdeveloped countries, saying that these countries could not be kept permanently in a state of bare subsistence by means of yearly

[1] Tibor Mende: *Le Sud-Est asiatique entre deux mondes*, Paris, 1954.

doles which only prolonged the agony without curing the disease. In the years that have since passed, however, no serious steps have been taken to cope with this problem. One has only to note that the amount allocated by the United Nations for the underdeveloped countries during the four years 1952–5 did not exceed 600 million dollars, whereas rearmament in the Western bloc alone absorbed over 55 thousand million dollars a year!

What explanation can there be for this apparent apathy on the part of the great powers in face of the critical problems of the present day? Instead of approaching these problems in a new spirit, they appear to be still thinking in terms of political principles which the march of events has long since made obsolete. Metternich's formula, 'Govern without changing anything', still has its adherents. When a people claims the right to self-determination, the dominating power usually finds a reason why the right should not be conceded. When an underdeveloped country asks one of the great powers for financial aid to enable it to develop its economy, the loan will not usually be forthcoming unless the borrower agrees to assume certain military or political obligations. When it is a question of developing the industrial use of nuclear power, the funds available are inadequate; but seemingly unlimited resources can be found for nuclear research and development for military purposes. As we have already seen, American budgetary appropriations for missile and new weapon development in the fiscal year 1957–8 will amount to something like \$6,000 million. On the assumption that the Soviet Union will be spending not less than this amount for the same purpose, we arrive at a total of \$12,000 million. If this vast amount of capital were devoted to atomic development in industry, or to providing underdeveloped countries with nuclear power, it is difficult to conceive how enormous would be the benefits that such a policy would confer on humanity.

¶ *Towards a state of economic rivalry between the two blocs*

In the absence of 'active co-existence', economic competition between the two blocs will gradually be transformed into a fierce rivalry which will dominate future international relations.

In this conflict the communist bloc will possess certain advantages which it will naturally endeavour to exploit so as to establish its own predominance.

Since the Second World War the initiative on the international political plane seems to have lain with the Russians. In a survey of the development of the international situation during the ten years following the war, M. Raymond Aron said that 'the form of international policy since 1945 has been determined by the tactics of Moscow'.[1]

If the communist bloc were able to retain this initiative during the next few years, it might well undermine the solidarity of the Western bloc and seriously endanger the stability of the American economy. If the Soviet Union and the other communist countries decided to multiply their protestations of fidelity to the policy of *détente*, to accelerate their disarmament, and to accept the American inspection plan, these tactics would do untold harm to the interests of the United States unless that country had, in good time, made the necessary adjustments in its economic policy and programme.

Another advantage which the communist countries possess over the Western countries lies in the present capacity of their economies to absorb, on no matter what price basis, any goods that any country may offer to them in exchange for their deliveries to that country. This is a factor of capital importance for the future orientation of international trade. What an underdeveloped country is primarily interested in is not the receipt of financial aid, but the possibility of selling its products. If this possibility does not exist, the country will continue to suffer from stagnation and depression. If other countries buy its surplus produce, they make it possible for it to develop its economy. The Burmese Prime Minister, Mr. U-Nu, regarded the agreement concluded with the Soviet Union as affording his country the possibility of overcoming its economic difficulties. After calling the Soviet Union 'the economic saviour of Burma', because of its undertaking to purchase Burma's rice surpluses, he said to Marshal Bulganin:[2]

[1] *Le Figaro* (Paris), 31 October 1955.
[2] *The New York Times*, 23 October 1955.

'Thanks to your purchases, we are now in a position to buy machinery and equipment from the U.S.S.R. and to make use of the services of Soviet technicians.'

A similar situation exists as regards Egypt, where the communist countries have to a certain extent cut out their Western competitors by buying the surplus cotton which Egypt was finding it difficult to market.

In this connexion the United States are handicapped by the structure of their economy. Themselves the producers of every conceivable kind of goods, often in excessive quantities, they are not in a position to absorb other countries' 'surpluses'. These surpluses may be insignificant in volume in relation to American consumption, but they consist of products which it is vital that the underdeveloped countries should be able to export.

Moreover, by reason of their protectionist policy, the United States cannot import the industrial products which the European countries wish to export. In his annual economic report, presented to Congress on 20 January 1955, President Eisenhower again invited the American parliament to adopt a more liberal international trade policy. He asked for authority to lower customs tariffs, to increase American investment abroad, and to intensify technical aid and other forms of economic support to the underdeveloped countries, particularly in Asia.

Congress, however, remains deaf to these recommendations, and does not appear disposed to lower the customs barriers which, in the words of Mr. Zellerbach, President of the National Manpower Council, 'are paralysing the free world'.[1]

The Soviet bloc can also compete with the Western bloc in the matter of prices. Its social structure, political system and rapid economic growth enable it to fix prices without having to take account of private interests—as the Western countries must do—or even of the traditional elements which enter into production costs. The Soviet authorities do not hesitate to give

[1] The secretariat of the Economic Commission for Europe, in a report on the difficulties in the way of export from Europe to the United States, stresses the obstacles created by the decision of that country to increase certain customs duties, and the importance of the demands made by American industries for the application of the safeguard clause.—See *Economic Bulletin for Europe*, November 1955.

political considerations the precedence over economic and financial considerations.[1]

Aid in the form of services and of *technical assistance* is of great importance for the underdeveloped countries, because of their lack of specialist personnel. The two blocs are vying with each other for the privilege of 'exporting' technicians to those countries. In an article on the training of scientific and technical personnel in the Soviet Union, *The Economist* arrived at the conclusion that 'impressive progress is being made, as a result of which that country has more "experts available for export" than have the Western countries'.

¶ *Competition among the Western countries*

In the economic struggle between the two blocs, the Western countries are handicapped by rivalry among themselves. The United States, Great Britain, Canada and France, which have hitherto held a dominating position in the markets of the 'free world', now have to reckon with competition from two great industrial powers, Western Germany and Japan.

The United States already sees that before long it will lose much of its former competitive capacity in certain markets, and particularly the European market.[2] A constant struggle goes on between the United States and Great Britain for the control of the sources of raw materials, and from time to time there is talk of 'price wars'. German competition is a cause of growing concern for Britain. A number of countries have adopted discriminatory measures to counter Japanese competition, an attitude against which vigorous protest was made by the Japanese delegation to the GATT conference at Geneva in October 1955.

Competition with the West will be further intensified when various other Asiatic countries make their appearance in the

[1] According to a report published in *The New York Times* of 26 October 1955, the prices charged by Czechoslovakia for weapons sold by it to Egypt were only one-fifth—and in some cases only one-tenth—of Western prices. According to a report in the *Journal de Genève* of 19 October 1955, Eastern Germany was subsidizing its exports to the extent of 75 to 80 per cent.

[2] The Chase National Bank's review, *Business in Brief* (September 1955), expressed the view that in future the countries most likely to provide expanding markets for American exports would be outside Europe, and, in particular, those which were suppliers of raw materials for industry.

world market in the near future. Delegates from Central Africa who attended the XVth Congress of the International Chamber of Commerce at Tokyo in April 1955 expressed the opinion that, sooner or later, the predominance of the Western powers in the African market would be seriously threatened by competition from the countries of the Far East.

¶ *The role of atomic energy*

The industrial exploitation of atomic energy will further modify this situation. The development of this new source of motive power will become a dominant factor in the economic struggle between the two blocs. The whole arsenal of scientific and technical skill will be mobilized. Armies of scientists, engineers and technicians will play a decisive part in the struggle. According to Admiral Strauss, President of the U.S. Atomic Energy Commission, the U.S.S.R. is each year producing over 60,000 trained engineers, against only 22,000 in the United States. Addressing a conference of American Air Force and aviation industry representatives on 15 February 1957, Dr. Edward Teller, a leading nuclear physicist who took a prominent part in the development of the hydrogen bomb, made the following 'gloomy prediction':

'Ten years ago there was no question where the best scientists in the world could be found—here in the United States. Today our leadership in science is being challenged by Russia . . . Ten years from now the best scientists in the world will be found in Russia. I am not saying that this will happen unless we take this or that measure. I am simply saying that it is going to happen.'

Dr. Teller added that he saw no way to maintain United States scientific supremacy, because of the long 'lead time' it takes to educate scientists.[1]

It is certain, however, that the United States will make a tremendous effort to overtake and outstrip the Soviet Union in this sphere. If this particular form of competition were to proceed in an atmosphere of hostile rivalry, it might rapidly become yet another threat to the peace of the world.

[1] *The New York Times*, 16 February 1957.

¶ *Necessity for a 're-thinking' of international policy*

It is clear from this brief exposé that 'static co-existence' is fraught with danger, and that there must be a radical change in present international policy, which is leading the world into an impasse and to ultimate suicide. Let us once again recall Einstein's warning: 'A new mode of thought is essential if humanity is to survive'.

It is our opinion that the Western countries should take the initiative in bringing about this change in policy. It is they who must seek to transform 'static co-existence' into 'active co-existence'—and that in their own interest, for they have nothing whatever to gain by 'static co-existence'. The continuance of poverty and misery in the underdeveloped countries, the existence of nationalist movements which fail to find satisfaction, and the clinging by certain of the great powers to an out-of-date colonial mentality: all these things create an atmosphere in which communism will flourish without any overt intervention on the part of the communist bloc. 'Take a map of the world', writes Bertrand de Jouvenel,[1] 'and note the progress of Soviet domination since 1945, all achieved by manoeuvring internal forces without implicating the Russian government . . . The Soviet blot on the map has become bigger and bigger, and will continue to spread without an international conflict.'

Is not the process described by M. de Jouvenel likely to be accentuated by a prolongation of this 'static mentality'? It is clear, therefore, that it is in the interests of the West to abandon the policy of 'static co-existence' as quickly as possible, and to replace it by a long-term policy providing for positive and effective action which, while safeguarding those interests, will at the same time ensure peace and prosperity for mankind as a whole.

4. THE PRE-CONDITIONS OF 'ACTIVE CO-EXISTENCE'

Only active and constructive co-existence can avoid the dangers of stagnation and ensure peace and prosperity.

If these objectives are to be attained, however, what must

[1] *La Gazette de Lausanne*, 10 May 1955.

be the nature of this co-existence? Neither of the two blocs has formulated the conditions necessary for effective collaboration. The Western nations, for the most part mistrustful and sceptical about co-existence, have not attempted to grapple with this problem. The Soviet government, for its part, has preferred to remain in the realm of generalities. In an interview with Harold Stassen on 9 April 1947, Stalin said that if there was to be any possibility of co-existence, neither side must indulge in criticism of the other's ideological system. There must be respect for the systems that had been approved and adopted by the peoples: on this basis alone would co-operation be possible. In a report presented to the Sixth Session of the U.S.S.R. Supreme Soviet on 12 February 1957, the then Foreign Minister of the Soviet Union, D. T. Shepilov, said that the peaceful co-existence of the socialist and capitalist systems was 'the cornerstone of the foreign policy of the Soviet state'. That policy, he said, was 'based on the immutable principles of respect for the sovereign rights of all countries, large and small, strictly observed non-interference in the domestic affairs of other countries and complete equality in relations with them.'[1]

Mr. Nehru and Marshal Tito have given the following formula for 'active and constructive' co-existence:

(1) respect by each side for the other's territorial integrity and sovereignty;
(2) non-aggression;
(3) non-interference in each other's internal affairs for whatever reason, whether economic, political or ideological;
(4) equality and mutual benefit;
(5) peaceful co-existence.

Although this formula—which was approved by the conference of Asiatic powers held at Bandoeng—is an interesting contribution to the study of the problem of international collaboration, it is not sufficiently concrete.

¶ *Necessity for a new policy*

The application of these five principles presupposes adequate

[1] *Soviet News*, London, 14 February 1947.

measures, both national and international, to ensure that co-existence shall be a permanent source of well-being. To achieve this there must be a radical revision of existing policies, a revision which in our opinion should be on the following lines:

On the national plane:

1. Rational administration of national resources on the basis of a long-term plan, and the pursuit of a policy of full employment, with a view to the development of the economy and the constant expansion of national income.
2. A social policy which, by an equitable distribution of the national income and a redistribution of surplus purchasing power, would ensure the raising of the standard of living of the population as a whole.
3. Nationalization of the large-scale productive units, as being an economic and functional necessity in the atomic age.

On the international plane: Parallel with the above internal measures, there must be an appropriate international policy if co-existence is to become a reality. We do not here propose to examine all aspects of such a policy, but shall consider three conditions which we believe to be indispensable, not only for peaceful co-existence but for a gradual advance towards complete world unity. These three conditions are:

(a) international co-operation to accelerate development of the peaceful use of atomic energy;
(b) a long-term economic agreement which would assure continuous and harmonious development of the world economy;
(c) the reduction of military expenditure, leaving ample funds available for financing the development of the underdeveloped countries.

¶ *Collaboration in peaceful atomic development*

Although neither of the two blocs, acting separately, could delay the utilization of atomic energy, or temper its impact on the

economic and social structure, they could, acting in common, 'guide' this industrial revolution in such a way that it would make the maximum possible contribution to world prosperity. For this to be possible, 'active co-existence' would be a *sine qua non*: in its absence there would be no possibility of avoiding the violent upheavals that would result from the sudden introduction of this mighty source of energy into economic life.

In the days of free competition any industrialist could, when a new technique gave him superior productive capacity, ruin and eliminate his less enterprising competitors without this being looked on as incompatible with the general interest. Today, however, economic phenomena must be regarded not from the narrow angle of private enterprise but from the point of view of the national economy as a whole. At a time when all countries are seeking to strengthen their productive apparatus, none of them can afford not to make use of new production techniques.

This is true not only for individual countries, but for the economy of whole continents. If tomorrow the scientists suddenly succeeded in controlling thermonuclear fusion, so that it became a source of power for industry, many of the existing means of production would be rendered obsolete and the resulting repercussions on the world's economy might well be disastrous. Until it had been possible to restore equilibrium by modernizing industrial installations, production would decline and this would automatically depress the standard of living in many countries.

If, however, there were common agreement upon a realistic policy designed to co-ordinate the use of the existing and the new nuclear techniques, in the interests of humanity as a whole, it would be possible to attenuate these repercussions and, what is more important, the benefits of this new industrial revolution would be attained more rapidly.

If this goal is to be attained, international co-operation, through the medium of the International Atomic Energy Agency, should have the following specific aims:

(a) Co-ordination of the efforts of all countries in the domain of nuclear science and technique, with a view to promoting

the utilization of atomic energy for industrial and other peaceful purposes. (Co-operation among the scientists and technicians, facilitated by the diffusion of reports and data, the holding of periodical meetings and the organizing of special congresses, would contribute enormously to the development of the peaceful utilization of atomic energy. Such co-operation should be directed above all towards solving the problem of harnessing thermonuclear fusion, a development which, as we have seen, would eventually reduce the production cost of electric power to zero. Nothing should be allowed to delay the pursuit of this last objective, and the necessary financial resources, however great, should be made available.)

(b) Training of nuclear specialists—scientists and technicians—which is the most urgent problem of the present day. (The main obstacle to the expansion of nuclear power production is neither of a technical nor of a financial nature, but consists in the acute shortage of trained personnel. It should be the duty of the International Atomic Energy Agency to take the initiative in promoting the preparation, on the national and the international plane, of training plans designed to remedy this shortage. There is need, in fact, of a world army of nuclear scientists and technicians if the full potentialities of atomic energy are to be exploited for the service of humanity.)

(c) Adoption of a long-term plan for the construction of nuclear power stations on behalf of the underdeveloped countries. (The construction of these stations would be shared out among the large atomic nations, and the necessary capital would be provided out of a special fund created by the main industrial countries. The beneficiary countries would be required to amortize the capital invested in these nuclear power stations over a period of from 30 to 50 years, and themselves to meet operating costs.)

In the present stage of nuclear technique, an annual capital expenditure of $2,000 million—equivalent to rather less than 2 per cent of the total amount now being spent on armaments—would permit of the construction, during a first five-year plan, of nuclear power stations with a combined installed capacity of at least 30 million kilowatts. To appreciate the significance

of such a plan, one has only to note that in 1954 the total installed capacity of the conventional power stations in Asia (excluding Japan) and Africa did not reach 10 million kilowatts.

When one realizes that at so relatively small a capital cost it would be possible to give the underdeveloped countries this most powerful means of combating poverty and misery, one cannot but be amazed at the indifference of the world's leaders in the face of a problem so urgent and of such social importance. How long will the United States and the Soviet Union continue to devote the fabulous sum of $8–10,000 million a year to nuclear weapon research, knowing that only one-fifth of this amount would suffice to bring about an enormous improvement in the standard of life in the underdeveloped countries?

¶ *The stopping of atomic and thermonuclear bomb tests*

It is obvious that real international co-operation with a view to accelerating the development of the peaceful utilization of atomic energy presupposes:

1. The *immediate suspension of experimental nuclear and thermonuclear explosions*, the continuation of which might be of great danger to the human race.

An official report drawn up by 23 scientists of world repute, and published by the World Health Organization, Geneva, on 13 March 1957, warns humanity of the harm that might be inflicted on future generations by the radioactivity emitted in these test explosions. These scientists are unanimous in affirming that this radioactivity may have dangerous consequences from the point of view of genetics. A Swedish scientist, Professor R. M. Sievert, has expressed concern at the discovery that, following nuclear explosions which took place in April and September 1956, cows in Sweden were producing radioactive milk and beef. In a report published on 20 February 1957, Japanese scientists asserted that if nuclear bomb tests were continued, the quantity of strontium 90 (a dangerous radioactive element in the fall-out from the testing of a hydrogen bomb) to which human beings and animals would become

exposed would constitute a serious menace. In this connexion it may be noted that the radioactivity of strontium 90 has an average duration of about forty years.

2. The *banning of the manufacture of atomic and thermonuclear bombs*. This ban would not only facilitate the concentration and co-ordination of international efforts to expedite the application of nuclear power to peaceful uses, but would, as we have seen above, have an immediate and considerable incidence on the production cost of nuclear power, by reason of the diminution of the demand for nuclear raw materials for military requirements.

3. Prior agreement regarding the *destruction of existing stocks of bombs* within a specified period—say two or three years. This interim would permit of the creation of an atmosphere of mutual confidence which would facilitate the final elimination of these weapons of war. If the technical research now in progress results in the discovery of an effective method of 'denaturing' the bombs in such a manner that the fissile material they contain can be used for peaceful purposes, the quantity of such material thus recuperated would of itself be sufficient to satisfy the world's needs for many years.

¶ *A long-term economic agreement*

Commercial relations between East and West at present rest on a basis of short-term bilateral agreements. This system works in favour of the communist bloc, since it enables it to adjust its commercial activities to serve whatever may be its predominant political interests for the time being. In a word, it is a system which works to the advantage of a 'dominant economy'. Here is what Professor Fr. Perroux has to say on this point:[1]

'When a dominant economy is in trade relations with another economy, and the trade effected between them represents only a very small proportion of the total foreign trade of the former economy, but a very considerable proportion of that of the latter economy, the cessation of this trade would barely be noticed by the dominant economy, but would be very keenly felt by the other.'

[1] *L'Europe sans rivages*, Paris, 1954, p. 92.

This contrast is still more marked when it is a question not of the 'dominant economy' of a single country but of that of a group of countries which have an identical social system, a combined population equal to more than one-third of total world population, and a very rapidly growing production.

The political orientation of any country is largely determined by economic considerations. Ideological preferences come second if they do not coincide with the country's vital interests. It is therefore natural that, in a divided world, the 'dominant economies' should increasingly endeavour to use their trade policy as a means of exercising influence of a political nature. This is true of the Western nations, just as much as it is of the Soviet Union and the Chinese People's Republic. Will the Western nations be able to avoid the consequences of a policy which tends to their disunion?

Will it be possible in the long run—in the absence of a general agreement between East and West—to prevent direct negotiations, when these are dictated by the vital needs of the individual countries? If in the future the Russians and Chinese, when concluding trade agreements with certain Western countries, were to couple them with political obligations, what could the other Western nations do about it?

Further, the ending of the 'cold war' would face the United States with the intricate problem of converting an economy with a high military content into a peace economy. (It will be remembered that the United States military budget amounts to $44,000 million.) If the United States were suddenly to decide to adopt a disarmament policy, it would simultaneously have to endeavour to find new markets capable of absorbing the output of the huge productive capacity previously devoted to supplying defence requirements. Unless they were successful in this endeavour, an economic crisis would be inevitable.

Short-term bilateral agreements—particularly in a situation in which there is relatively little trade between the United States and the countries of the East—provide no satisfactory solution of the world's economic problems. If the expansion of world economy is to be assured, this can only be on the basis of a multilateral trade agreement between East and West,

established in the first instance for a period of, say, five years and automatically renewable thereafter. Within the framework of this general agreement, triangular trade arrangements could iron out certain problems which cannot satisfactory be solved within the restricted scope of bilateral agreements.

The basic principles of this agreement should be laid down by the United Nations Organization, but the commercial transactions under the agreement should be arranged through a special organization which would perform the functions of a clearing agency. In order that this organization should be able to operate efficiently, it would be desirable for its administration to be entrusted to representatives of the great powers which hold a predominant position in world trade. We believe that such an agreement could immediately ensure trade between East and West to the value of something between 5,000 and 10,000 million dollars per annum, with every prospect of an uninterrupted growth in turnover.

This estimate does not appear exaggerated when it is noted that the Economic Section of the conference known as the 'Rencontre pour la Détente Internationale', which met at Stockholm in June 1954, and in which representatives of the Soviet Union and of the People's Republic of China took part, considered that 'the volume of east-west trade could rapidly reach a level of 3,000 to 5,000 million dollars per annum' and that this 'would not be the limit of the possibilities in this domain'.

Co-operation on such a basis would give the industrialized countries the assurance that their productive capacity would be fully employed for many years to come, that there would be a market for their surplus production, and that the manufacture of armaments could be reduced without causing an economic crisis. Moreover, the underdeveloped countries would be able to obtain the means of production which they need for the exploitation of their own natural resources.

The desire for such co-operation is manifest in both East and West. In an interview which the writer had with Mr. Chou En-lai, Prime Minister of the People's Republic of China, in Pekin in September 1956, the latter said that he was in favour

not only of a long-term trade agreement between East and West, but also of a long-term economic agreement between China and the United States. He was convinced that such an agreement between those two countries would not only be to their great mutual benefit but would make an important contribution to the lessening of international tension. The Soviet leaders have also repeatedly expressed their desire to see an expansion of trade between East and West.

So far as the attitude of the West is concerned, increasing interest is being shown in the development of trade relations with the East, and especially with China. On 15 March 1957 the Federation of British Industries launched a campaign to foster such development. In the United States, the President of the Ford Motor Company, speaking on 29 January 1957, forecast a 'new look' in commercial relations with the East, and with communist China in particular.

We must hope that this mutually held desire will speedily be realized. For our part, we believe that a long-term commercial agreement is an indispensable part of the basis of any system of peaceful co-existence, and that it would open the way to a real *détente* and to mutual understanding.

¶ *Reduction of armaments and increased aid to the underdeveloped countries*

There can be no lasting freedom from international tension unless there is a massive reduction in military expenditure, which is at present extremely high in relation to national income. This expenditure reduces the resources available for productive capital investment, constitutes a permanent factor of inflation and depresses the standard of living in many countries. The cutting down of this expenditure would make funds available which would be placed at the disposal of the backward countries to enable them to exploit their natural resources, increase their agricultural and industrial production and absorb any unemployment or underemployment. The highly industrialized countries should devote part of their savings on armaments to the financing of the underdeveloped countries, in accordance with an international agreement

which would provide for the utilization of the funds on an impartial and non-political basis.[1]

Addressing American newspaper editors on 16 April 1953, President Eisenhower said:

'Every gun that is made, every warship launched, every rocket fired signifies—in the final sense—a theft from those who hunger and are not fed, those who are cold and are not clothed. . . . The cost of one modern bomber is this: a modern brick school in more than thirty cities; it is two electric power plants, each serving a town of 60,000 population; it is two fine, fully-equipped hospitals. . . .'

Today, four years after those words were spoken, the great powers are still devoting colossal sums to the development of atomic and thermonuclear weapons. A single guided missile costs something like a million dollars!

It may be noted that a reduction of 25 per cent in the present military expenditure of the United States, the Soviet Union, Great Britain and France (to mention only the four great powers) would mean a yearly saving of at least 10,000 million dollars. These funds could not only provide the underdeveloped countries with financial aid urgently needed for their economic development. but would constitute for the industrialized countries an effective means of absorbing their production surpluses.

Such an arrangement, coupled with the long-term general trade agreement, would make good the deficiencies in the various national economies, stimulate and regularize the flow of international trade and ensure the harmonious development of world economy as a whole.

The realization of these three conditions (international co-operation in the atomic sphere, a long-term economic agreement and the reduction of military expenditure) would provide a firm foundation for an international policy which could at any time be adjusted to bring it into line with changing conditions; would ensure that the whole world participated in the

[1] The writer had an opportunity of giving a more detailed exposition of these views at the 'Rencontre pour la Détente Internationale', at Stockholm, in June 1954. Similar views were put forward at the Geneva Conference of the Big Four in July 1955 by the then Prime Minister of France, M. Edgar Faure.

benefits of the great industrial revolution that is now taking place; and would give mankind a fuller and richer life in an atmosphere of peace.

¶ *The United Nations Organization must be directed by the 'Big Six'*

The realization of such a policy cannot, however, be assured by the United Nations Organization as it functions today. Experience has shown that U.N.O. is unable to bring about a satisfactory solution of the problems in suspense. It is fearful of assuming responsibilities and its capacity to act is paralysed by the conflicting interests of the great powers. It is vitally important that U.N.O. should continue to function, but it must be rendered capable of dealing with world problems in a 'universal spirit' and of enforcing its decisions without consideration of sectional interests. In order to make this reform possible, the administration of the organization should be entrusted to an Administrative Council which would draw up general directives for international policy and submit them to the General Assembly for approval. This Administrative Council should consist of representatives of those great countries which together contain the major part of the world's population—that is to say, not merely those countries which are economically and militarily the most powerful.

The countries which, on this criterion, should constitute the Administrative Council are the following:

1. United States of America.
2. Soviet Union.
3. Great Britain (also representing the Commonwealth, excluding India).
4. People's Republic of China.
5. India.
6. The countries of Western Europe (represented by delegates nominated jointly by the member-countries of the Western European Union).

A Council thus constituted, representing an aggregate population of over 1,600 million, or about 70 per cent of the total population of the globe, would, we believe, be the most

appropriate organ for formulating international policy in the atomic age. Meeting at the conference table in the knowledge that the only hope for the future of humanity lay in 'peaceful co-existence', surely these representatives of the leading nations would approach the world's problems in a realistic and constructive spirit which would exclude sterile propaganda or 'procedural' obstructiveness.

In an editorial article in the *Gazette de Lausanne* of 19 February 1957, M. Georges Rigassi wrote: 'The survival of the United Nations Organization will depend on the energy with which it devotes itself to bringing a renewal of hope to the anxious and disillusioned peoples of the world.' We believe that the fulfilment by U.N.O. of this condition of its survival will only be possible if the administration of the organization is reformed in a manner such as we have just suggested. Participation in the administration by the two great Asiatic powers, China and India—whose role in the world will be immensely enhanced by the advent of the atomic age—would tend to attenuate the antithesis between the 'rich countries' and the 'poor countries', and would facilitate that reconstruction of the geopolitical map of the world which must be the inevitable outcome of the industrial revolution of the 20th century.

5. FROM CO-EXISTENCE TO WORLD UNIFICATION

The policy we have envisaged for transforming 'static co-existence' into 'active co-existence' will undoubtedly be considered by many people to be impracticable in the conditions now prevailing in the international sphere. While not underestimating the difficulties, we believe that that policy offers the only means of getting out of the present impasse, of establishing genuine co-existence between the two opposing blocs, of gradually bringing the two blocs closer together, and of avoiding a perilous economic, political and ideological struggle.

¶ *A quasi-obligatory evolution*

This movement towards a state of active co-existence between the two opposing social systems, accompanied by a gradual narrowing of the gap that now separates them, will take place whether

we like it or not. Even if the great powers are not willing to commit themselves to a policy of 'active and constructive co-existence', that situation will ultimately be imposed by the march of events—economic, social and political—but this period of evolution will then be one of stress, disturbance and possibly violence.

Merely on the basis of the probable repercussions of atomic development that have been outlined above, the general course of international events in the near future may be forecast as follows:

Firstly: The present state of 'cold war' may be expected to continue until 1960–2, with alternating phases of *détente* and tension; the two blocs will not during this period make their final choice between peace and annihilation. Nuclear tests will probably cease under the pressure of public opinion, but the atomic armament race will continue, and particularly the feverish scramble to be the first to possess the 'ultimate weapon'. There will continue to be local conflicts in various parts of the world, with the United Nations powerless to impose satisfactory settlements. The struggle among the great powers to extend their respective 'spheres of influence' will be intensified.

This will be the most fateful period in the history of mankind, for a simple misunderstanding may be sufficient to precipitate a war that would bring that history to a tragic close. Governments will base their hope of averting catastrophe solely on the efficacy of the so-called 'strategy of intimidation'.

Secondly: From 1960–2 onwards the growth of the industrial use of nuclear power will assume such proportions, and the cost of its production will become so small, that all countries—and above all the underdeveloped countries—will make every effort to acquire the greatest possible number of nuclear power stations to satisfy their power requirements. The creative aspect of the atom will eclipse its destructive potentialities, with the following consequences:

(a) All the 'atomic countries' will do everything in their power to enter the international atomic market with the best possible equipment and in the most advantageous conditions. This will be the beginning of a period of economic rivalry,

particularly between the two blocs, each of which will endeavour not only to acquire new markets but also to demonstrate the supremacy of its own social and political system.

(b) Aid to the underdeveloped countries in the atomic sphere and in the exploitation of their natural resources will constitute a trial of strength between East and West in the early years of the period. This will cause each country to endeavour to free itself of any financial burden that might place it at a disadvantage in this competition. Inevitably, therefore, there will be a progressive reduction of military expenditure, which would be the major handicap from the point of view of competitive capacity. Thenceforward the power and prestige of each nation will be assessed not according to its strength in atomic and thermonuclear weapons (the utility of which ceases, once a certain level has been reached), but by its capacity to produce nuclear power plants, to supply them on reasonable terms to other countries, and particularly the underdeveloped countries, thereby making an invaluable contribution to the latters' economic progress.

(c) This competition between East and West, which will inevitably take place in an atmosphere of hostile rivalry, will have far-reaching repercussions on the economic structure of the Western countries, whose production and prices are determined by private enterprise according to traditional economic and financial criteria. Large private industrial enterprises whose operations are directly or indirectly dependent on electric power will be unable to stand up to the competition that the communist countries will develop under a long-term plan which will be largely inspired by political motives. Such enterprises will collapse unless the state steps in to save them by means of subsidies. The communists will do all they possibly can to assist the downfall of industrial capitalism which, according to Marxist theory, is in any case doomed to ultimate extinction.

Thirdly: From 1960–2 onwards there will, on the other hand, be a gradual easing of the tensions in international relations as a result of the industrial utilization of atomic energy. The most important repercussions of this utilization will be:

(a) A progressive decline in the importance of certain regions of the world that are at present vital sources of energy and, as such, focal points of international tension. Thus, with the generalization of the use of atomic energy (which not many years hence will be produced locally wherever it is needed), the Middle East will cease to be a pawn in the great-power game and will become a peaceful region that no longer bedevils international relations. Similarly, the Sahara, which because it is now believed to possess rich oil deposits is considered by many people to be France's 'big chance', will cease to be an obstacle to the attainment of economic and national independence by the countries of North Africa, for France will cover her energy requirements by developing the industrial use of nuclear power.

(b) Technical progress in the production of nuclear weapons, and particularly of intercontinental guided missiles, will render the territorial bases of the great powers highly vulnerable and thus enormously diminish their importance. This development should facilitate the discarding of such bases, as part of some general disarmament scheme.

(c) The entry into the international arena of the underdeveloped countries, and of China and India in particular, will conduce to the establishment of a new equilibrium in the distribution of economic and political forces, and thus to the lessening of international tension.

Fourthly: The present leading countries of the world—in other words the industrial countries—will by 1970–5 be experiencing the 'recoil' that will follow the impact of atomic energy on economic life. The generalization of the peaceful use of atomic energy during the period 1965–75 will result in the industrialization of the countries which are the producers of raw materials, that is to say the countries which are today the underdeveloped countries. The fact that it will be possible in future to produce electric power wherever it is needed, and at a price that will not depend on the place of production, will mean that new industries will be established in regions where up to the present this has been impossible. There will thus be a profound change in the economic geography not only of individual countries but of the world as a whole. It does not

seem excessive to predict that by about 1975–80 the countries of Asia may be furnishing 30 per cent of total world production, instead of only 10 per cent as at present; and that by the year 2,000 the proportion will have risen to about 50 per cent.

How will this affect the situation of the present industrialized countries? Their future will depend on the nature of the prevailing system of co-existence. If the re-drawing of the geopolitical map of the world takes place in the absence of close international co-operation and in an atmosphere of rivalry, it is difficult to see how economic crisis can be avoided in the great industrial countries. What is certain is that, if such an atmosphere exists, the Soviet Union will do all in its power to create the greatest possible difficulties for capitalism and, in particular, to force the American economy into a prolonged crisis which might become so serious as to give the *coup de grâce* to the system of private enterprise.

If, on the other hand, the geopolitical readjustment took place in a situation of 'active co-existence' such as we have described, crisis would be avoided, the transition to the new social structure would take place peacefully, without disruptive or violent repercussions, and the well-being of humanity would be assured. The needs of the world are so numerous and pressing that all means of production, whether old or new, should be applied to their satisfaction and to the ensuring of world progress, prosperity and peace. If as a result of hostile rivalry an economic crisis were to render a certain number of these means of production unusable, this would delay the amelioration of the standard of life of many peoples.

¶ *Active co-existence a necessity in the atomic age*

On the assumption, however, that in a state of 'static co-existence' events would take the course we have described, it may be asked what interest the Soviet Union would have in helping to bring about a state of 'active co-existence'. The answer is that active co-existence is an imperative necessity for the Soviet Union, just as much as for the rest of the world, for the following reasons:

(a) The continuance of international tension compels the

Soviet Union to devote a large percentage of its national income to rearmament. This acts as a brake on economic development and limits the possibilities of raising the standard of living of the Soviet people.

(b) Economic competition between East and West, if carried on in a spirit of hostility, would adversely affect the standard of living in the communist countries, and this—as recent events in Poland and Hungary have shown—would create a standing menace to the stability of the communist régime.

(c) A continuance of international tension would foster resistance to the communist régime by hostile elements in the peoples' democracies. This would keep those countries and the Soviet Union in a constant state of 'alert', and would make it necessary to postpone any steps in the direction of 'democratization' and 'desatellization'. A psychological atmosphere would be created which would engender revolts that might easily develop into civil war and finally into a generalized conflict.

These are some of the reasons which will compel the Soviet Union, China and the other communist countries to seek active co-existence and, indeed, to make such concessions as may be necessary to achieve it. It must, however, be added that active co-existence will be a more pressing necessity for the communist countries between now and 1960–2 than it will in the ensuing period. For the Western world the situation will be rather the reverse: their necessity for active co-existence will become more urgent from 1960–2 onwards.

These contrasting positions may be an obstacle to the realization of active co-existence. If, however, 'co-existence' represents a 'compromise' between opposing interests, would not the Western nations have every reason to adopt the 'active co-existence' policy now, while the Soviet Union is still passing through its 'critical period'? Today it is the Soviet Union which is eager for co-existence: tomorrow it will be the Western nations. If when tomorrow comes the Soviet Union imposes 'conditions', what will the West do? It is perhaps unnecessary to remark that *policy* is above all a matter of *foresight.*

In any case, active co-existence is, as we have shown, a necessity of the atomic age. It would serve the best interests of

both blocs, and thus of all peoples and countries. Any delay in arriving at an agreement establishing active international co-operation will undoubtedly be prejudicial to the interests of humanity and increase the difficulty of maintaining peace. It is therefore the duty of all those who can exercise any influence upon the world's leaders—and this applies particularly to the men of science—to take the initiative in mobilizing public opinion not only in support of negative objectives such as the banning of the atomic bomb and the stopping of thermonuclear tests, but also, and above all, in support of the constructive task of bringing about a state of active co-existence, in order that the immense benefits of atomic energy may be placed as rapidly as possible at the service of humanity as a whole.

¶ *Towards a world confederation*

The establishment of a state of co-existence such as we here contemplate could lead by stages to the unification of the world. If by agreement among the great powers it were possible to accelerate the utilization of atomic energy to serve the needs of the peoples of all countries; if the universal availability of atomic energy led to a 'socialization' of capitalism and a 'democratization' of communism; and if the new industrial revolution led to close co-operation among all countries—we see no reasons why the United Nations Organization should not become all that its name implies and, to a certain degree, perform the functions of a world government.

This would not mean a complete fusion of the nations of the world, but the creation of a broad confederation within which each country would be free to develop its own national characteristics and potentialities. Switzerland is a living demonstration of the possibility of combining within a single closely knit community distinct territorial units which, while differing in language, customs and traditions, possess a common economic and social structure.

The essential objective of such a confederation must be the constant improvement of the standard of living of all its peoples, and in the pursuit of this objective there must be full respect

for the liberty of the individual. Only in such a community can there be any meaning in the words 'the dignity of man' and any real advance in culture and civilization. In the second half of the twentieth century the prodigious progress of science and technology will, by enabling man to free himself from his material servitudes, offer him the possibility of attaining a level of cultural development hitherto unknown.

Progress towards world unity, however slow and uneven it may have been, runs as a continuous thread through history, and the desire of humanity to reach that goal has never been stronger than it is at present.

My thoughts go back to early school-days and I remember the childish wonder with which we listened to our teacher's account of the history of our Greek ancestors. How incomprehensible it seemed to us that cities whose inhabitants were all of the same stock should have been constantly engaged in bitter struggles the one with the other: Sparta with Athens, Athens with Corinth, Corinth with Thebes . . . In Ancient Greece each 'city' was an independent kingdom, a sovereign state. But Greece has long been a united nation.

The history of many other countries records a similar evolution. In the course of time numerous small sovereignties have, after long periods of rivalry and wars, finally combined to form nations. Only a score of years ago the world was very sharply divided into a large number of nations, each jealously guarding its independence. Today we are witnessing a trend towards the grouping of nations. In the West 'integration' is the theme: in the East a more and more cohesive bloc is in process of formation.

If we can free ourselves from our prejudices, our chauvinism and our petty obsession with short-term interests; if we can widen our narrow perspective to embrace the whole world-scene; then we shall find ourselves capable of overcoming all the difficulties of the present age, and of advancing cautiously but confidently along the final stage of the journey which will lead to that unity which is humanity's goal.

The atom, with its immense potentialities, will not only

accelerate this evolution towards unity: it will make it inevitable. Whether we will or not, the atom is destined to unite the world. It will do so either through Peace or through War: the choice rests with man. The whole future of humanity depends on our ability to comprehend the significance of the atomic age.

Geneva, May 1957